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# A FILTRATION AND WATER CONTROL SYSTEM FOR THE PROPOSED UNDERWATER ACOUSTIC TEST FACILITY

Prepared by:
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ABSTRACT: This report presents a discussion of a filtration and water control system for a proposed underwater acoustic test facility. It specifies functional requirements for the components and subsystems of a filtration system and, based on these requirements, it presents a detailed design for such a system.

U.S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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A Filtration and Water Control System for the Proposed Underwater Acoustic Test Facility

This report describes a system for handling and filtering water in a proposed underwater acoustic test facility. The report develops criteria for the selection of components, specifies subsystem functional requirements, and presents a detailed design for the complete system. The Task Numbers covering this work were ORD 054-000/U2315 problem 603 and ORD 534-470/U3801 problem B01.

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GEORGE G. BALL
Captain, USN
Commander

J. SCHROEDER
By direction

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ILLUSTRATIONS

## ILLUSTRATIONS CONT'D



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# Chapter 1

## A Survey of the Problem

1-1 This report describes the filtration and water control system for a proposed new underwater acoustic test facility. The report discusses the need for filtration in such a facility, and points out some of the special requirements on the system because it is in an acoustic test facility. Theory and methods of filtration of water and some criteria for the selection of components for the proposed filtration system have been described in internal reports (EED Communications 4415 and 4425, and NOL Technical Note 8549). This report will present and discuss schematic diagrams of the proposed water control system, its subsystem, and its major components.

1-2 As reference (a) pointed out, the design concept for the total facility was divided into four areas of responsibility: (a) the building and associated equipment, (b) the electro-acoustic system, (c) the transducer positioning and handling system, and (d) the filtration and water control system. That reference also described some of the electro-acoustic requirements for the total facility. Some of those requirements may be interpreted either directly or indirectly as functional and operational requirements on the water control system. Those requirements, which will be discussed later in this paper, demand that the filtration and water control system be considered in somewhat more detail and with a higher level of concern than would be required for another body of water, such as a swimming pool, that would not be used for acoustical investigations. In fact, minimization of noise in the water control system and simplicity of its operation have been the pre-eminent concerns in its design. But before one can appropriately discuss the design of the filtration and water control system he should consider the question, "Why is filtration necessary; why isn't the normal drinking water from the municipal water main clean enough for underwater acoustical investigations?"

### THE NEED FOR FILTRATION

1-3 There is nothing wrong with the drinking water in the geographical area of the Laboratory where the proposed test facility will be constructed. The water in the area is perfectly acceptable for human usage as is confirmed periodically as a part of a routine survey by the Laboratory in co-operation with the Washington Suburban Sanitary Commission. A technician inspects the water for clarity, measures the pH, and collects a sample which is sent to the Washington Suburban Sanitary Commission. There has never been any question about the safety of the water for drinking purposes; but, ordinarily, this type of water usage does not require high flow rates such as will be required in the proposed test facility. A demand for a high flow rate from a seldomly used city main can bring forth rocks, mud, and pipe-scale for several minutes until the mains are purged. The author has observed such a phenomenon when he asked the Laboratory plumbers to open a fire hydrant in the general locality of the proposed new facility. The water from the five-inch hydrant produced rocks and mud, and the water, flowing at about 100 gallons per minute, required about six minutes to reach a reasonable degree of clarity. Occasionally, the proposed test facility will require large volumes of water at high flow rates. It is desirable, therefore, that any new water introduced into the test facility be well filtered in order to remove the normal accumulation of mud and scale. But this is not the only, nor the most important, reason for having a filtration system in the new facility.

1-4 Any stationary open body of water will become contaminated with airborne dust and dirt, and eventually will become an excellent culture for the propagation of bacteria and microscopic plant life. Chemicals can reduce this tendency, but, after awhile, the character of the water will have changed considerably; it will be a suspension of contaminants and chemicals with a bottom layer of precipitated matter. If foreign bodies are submerged and removed from the body of water, such as will be the case in the proposed test facility, the accumulation of debris in and out of suspension will occur at an increased rate. It becomes rather evident, therefore, that water confined to a test tank should be changed periodically by one means or another. Over a long term, the most efficient, economical, and intellectually pleasing method of accomplishing this is to continually circulate the water in the tank through a filtering system. This is the method proposed for the new test facility. But the introduction of such a system introduces additional sources of contamination, such as pipe-scale and corrosion. The design of the filtration and water control system presented in this paper attempts to account for and reduce the contaminant contribution from these sources.

SPECIAL REQUIREMENTS

1-5 The reader's attention is called to the fact that the above discussion has not related the requirements for clean water in a closed test tank to the fact that this paper is concerned with an underwater acoustic test facility. Consider, then, some of the additional requirements that this use of the facility will impose on the water control and filtration system.

1-6 The most pertinent such requirement on the filtration system is that it introduce a negligible amount of noise into the test tank. The reason for this is that hydrophones to be tested in the facility may detect any such noise; the electrical output from the hydrophones would then contain signals not solely due to the controlled and known test signals from the standard projector also submerged in the test tank. This would, of course, make interpretation of the hydrophone's output signal difficult, and would impair measurement precision and accuracy of the test facility. As mentioned above, noise reduction has been a pre-eminent concern in the design of the facility and water control system. To accomplish a minimum feasible level of noise interference between the filtration system and the water tank, two primary sources of noise had to be considered -- the piping and the pumps.

<u>NOISE IN PIPING</u>. The source of noise in piping is the interaction between the fluid moving in the piping, and the walls and junction points of the plumbing system. One such interaction, which becomes rather violent at times, is called "water hammer." Water hammer is not expected to be a problem in the proposed facility, but a brief discussion of it is worth-while since it will be possible to encounter it under certain conditions in the facility.

<u>WATER HAMMER</u>. As reference (b) describes it, the problem of water hammer in a pipe-line consists of containing the pressure and dissipating the water flow energy. For example, in a pipe-line with a supply pump, energy necessary to move the water through the piping is supplied by the pump. If a valve is suddenly closed at the end of the discharge line, the moving column of water is brought to a stop at the valve. The kinetic energy contained in the column of water, originally given to the water by the pump, is still present and must be dissipated. The column of water compresses, the pressure rises, and some of the kinetic energy is transformed into internal energy. The higher water pressure acts upon the pipe wall and does work in stretching it, but only a small percentage of energy will be lost in this. The pipe will obey the laws of vibration and return most of the energy to the water. The energy or pressure wave which started at the closed valve, stretches the diameter of the piping progressively to its source, the pump. The energy-wave front may meet a check valve at the pump and be reflected back towards its origin, continuing its dissipation of energy within the water and the pipe wall. This will continue until the kinetic energy is fully

converted to internal energy. In other words, if the velocity of water flowing in a pipe is suddenly diminished, the energy given up by the liquid will be divided among compressing the liquid itself, stretching the pipe walls, and frictional resistance to wave propagation. Water hammer is manifest as a series of shocks sounding like hammer blows which may have sufficient magnitude to rupture the pipe or damage connected equipment. The velocity of the wave is that of an acoustic wave in an elastic medium, the elasticity of the medium in this case being a compromise between that of the liquid and the pipe. Complete stoppage of flow is not necessary to produce water hammer, as any sudden change in velocity will create it to a greater or lesser degree. The rise in pressure caused by water hammer may be minimized by the use of relief valves, surge tanks, or air chambers. As a rule, however, these water hammer suppressors do not eliminate shock entirely, but will reduce it by 10% to 40%, which often is sufficient to remove the clanking sound.

FLOW NOISE. The noise producing interaction between the water and the piping that has been of most concern in designing the filtration system for the proposed facility under discussion is flow noise -- noise caused by the normal flow of water in pipes, around joints, and through valves in the piping system. As reference (c) points out, the nature of flow noise is not very well understood. It may be associated with turbulence, and, if it is, it can be controlled by design. There is evidence, however, that noise is produced by the flow of water even when turbulence is absent; if this is true, there will always be such noise when water is moving with respect to its container walls. In any case, the concern in the filtration system is to minimize the flow noise generated in the system no matter what its cause. To accomplish this minimization of flow noise, one should have some elementary understanding of the flow of liquids in pipes.

1-7 The Bernoulli Equation is of great usefulness in dealing with the flow of liquids. One form of that equation is

$$H = V^2/2g + P/w + z$$

where H is referred to as the total "head" of the fluid and is made up of three components. The first term, $V^2/2g$, has the dimensions of feet and is called the "velocity head." The second term, P/w has the dimension of feet if P is expressed in pound force per square foot, and W in pound force per cubic foot; the ratio is referred to as the "pressure head." The third term, z, represents the "static head" of the fluid, and its dimension is also feet. Expressed in words, this equation states that in the steady, incompressible flow of a frictionless fluid, the total head is equal to the sum of the velocity head, the pressure head, and the static head. In actual practice, however, friction does occur as the fluid flows from one portion of the piping system to another. The effect of friction, then, is taken into account by adding a term, $h_f$, to the equation; this is a friction head term.

1-8 Another equation that is useful in dealing with the flow of liquids is the continuity equation for one-dimensional flow:

$$\sum(\rho AV)_{inlets} = \sum(\rho AV)_{outlets}$$

where $\rho$ is the density of the fluid flowing in the pipe, A is the cross-sectional area of the pipe, and V is the velocity of the fluid in the pipe. Since the product of $\rho AV$ has the dimensions of flow rate, such as gallons per minute (gpm), this continuity equation says that, for incompressible liquids, the quantity of liquid entering a closed system per unit time must equal the quantity of liquid leaving the system during the same time.

1-9 In addition to the equation of continuity and Bernoulli's Equation, which govern the fluid flow, another equation that is sometimes helpful in understanding fluid flow noise is the equation for Reynold's Number:

$$N_r = VD\,\rho/\mu = VD/\nu$$

where $\rho$ is the density of the fluid flowing in the pipe, V is the velocity of fluid flow, D is some significant length which, in pipe flow, is usually taken as the geometric diameter; $\mu$ is absolute or dynamic viscosity, and $\nu$ is kinematic viscosity. Reynolds Number, named after Osborne Reynolds who first noted its significance in fluid flow problems in 1883, is a dimensionless ratio and serves as an index used in predicting changes in flow character; one should not attempt to think of the Reynold's Number in terms of a definite, physical meaning. In his original experiments with the flow of water in pipes, Reynolds found that at values of Reynolds Number of about 2,000, the flow character changed. Below 2,000 he found the flow to be smooth and steady with no intermingling of particles from one apparent layer of fluid to the next; he called this laminar flow. Above values of 2,000 Reynolds found that the fluid flow became disturbed and agitated, and that the flow could no longer be characterized by layered flow because the particles from the former adjacent layers intermingled; he called this turbulent flow.

1-10 Consider an example of the value of Reynolds Number that might be expected in the filtration system. Suppose the flow velocity in a four-inch pipe is chosen to be 3.5 feet per second. From tables, we know that $\nu$ equals $10^{-5}$ feet squared per second at about 75°F. The Reynolds Number for this situation is then given by the equation

$$N_r = VD/\nu = (3.5)(4/12)(10^5) = 1.17 \times 10^5$$

i.e., the flow would be turbulent since this is much greater than 2,000. From this realistic example, then, it appears that it will be highly impractical to try to make the flow in the filtration system approach the conditions of laminar flow. This fact, of course, should not be considered as ominous: it is just a condition that practical design considerations will have to minimize or surmount in more devious ways than by using larger pipe sizes. But rather than further considering this flow noise problem from a mathematical point of view, consider a teleological argument.

1-11 One would expect the noise associated with the flow of the water in the piping system to be increased where there are constrictions and deviators of flow direction, such as valves, scale or corrosion deposits, and elbows. To minimize these difficulties, the design should attempt to use (a) a minimum number of throttling or control valves which operate by constricting the flow; full-port valves should be used for a simple on-off operations; (b) compatible and non-corrosive materials such as the poly-molecular plastics, wherever possible; and (c) a minimum number of elbows, tees and other devices that abruptly change the direction of the water when it is moving at high flow velocity.

1-12 We can summarize this discussion of flow noise by saying that after these foregoing conditions have been optimized in the design of the filtration system, it is then reasonable to fall back on a consideration of the factors that contribute to flow noise, that are included in Reynolds Number. These are the dynamic characteristics of the fluid flow, and the static characteristics of the piping dimensions which were discussed above.

<u>PUMP NOISE</u>. Last to be considered, but first in importance in generating noise in the filtration system, are the pumps. The sources of noise in the pumps are the usual mechanical noises associated with the interaction of the pump impeller with the fluid being pumped. Motor noise and vibration arise from the rapid rotation of the armature in the stator. Much of this type of noise and vibration can be minimized by the selection of quiet operating pumps, such as might be used on submarines, and by mounting the motor on a vibration-suppressing foundation. The noise and vibration generated by the interaction of the pump impeller with the fluid being pumped are manifestations of cavitation, which adversely affects pump performance and may damage pump parts, as reference (d) explains. This type of noise and vibration is caused by the sudden collapse of vapor bubbles as soon as they reach the high-pressure zones within the pump; the bigger the pump, the greater the noise and vibration. These signs of cavitation may appear in the normal operating range of the pump only if the suction head is not sufficient to suppress cavitation. Noise and accompanying vibration, however, are present in all pumps to a varying degree when they are operated at points far removed from their best efficiency point. This is because of a bad angle of attack at the entrance to the impeller (reference (d)). Reference (d) also points out that noise can be almost completely eliminated by admitting small amounts of air into the pump suction to serve as a cushion when the vapor bubbles collapse; this method is not often used, however, to eliminate noises in centrifugal pumps. Its beneficial use in water turbines under cavitation conditions helps reduce or eliminate vane pitting caused by the mechanical shock accompanying the collapse of the vapor bubbles, but the best solution to the problem of impeller generated noise and vibration to incorporate a suction head large enough to suppress cavitation and to select the properly designed impeller and pump casing for the required pumping conditions. Most pump manufacturers are more than willing to supply the necessary information for making these selections.

1-13 Noise, wherever it is generated in the filtration system, will tend to deteriorate the accuracy and precision of acoustic measurements in the new facility. It is important, therefore, that every effort be made in designing the system to minimize noise generation. No matter how successful the design is in approaching this goal, however, it is anticipated there will still be a significant level of noise generated. The next obvious step, then, is to try to reduce this remaining noise and to prevent its transmission into the main testing tank.

REDUCTION OF NOISE TRANSMISSION. The desirability of mounting the pumps on vibration-suppressing foundations was just mentioned. This is one method for reducing the transmission of the noise generated by the pumps. Another method, which will also be incorporated in the new facility, is to use acoustical decoupling junctions between the piping system and the suction and discharge nozzles of the pumps. One such decoupler available on the market is a heat-resistant, synthetic, flexible rubber pipe with a woven multi-ply rayon and helical steel wire reinforcement throughout.

1-14 Transmission of air-borne noise will be reduced by confining the major noise sources inside a small, acoustically insulated room in the basement of the proposed facility. Air-borne noises should not present a significant problem in this facility because of the large acoustical impedance mismatch between the air and the wooden testing tank. The main area of concern for noise transmission into the testing tank is through the portions of the piping system that are physically in contact with the tank itself, or with the water in the tank. This transmission capability of the pipe is one criterion for use in selecting the piping materials for the proposed facility; other criteria are some of the chemical and physical properties of the piping material. To make a discussion of these factors more germane, however, it is important to know some of the other overall requirements on the character of the water circulating in the closed-loop filtration system. The primary requirements can be summarized by saying that the objective of the filtration system in the planned test facility is to make the water have as little effect as possible on acoustic signals transmitted and received in it. This acoustical purity requirement is roughly equivalent to calling for optical purity, or photographic purity in the water.

FILTRATION OBJECTIVES

1-15 The source of the water for the planned facility will be the laboratory main. As pointed out above, the water in this main has been purified to a level safe for drinking, but the geographical location of the proposed facility will require that it be near the end of the primary supply line in the laboratory. Experience with large volume water flow from this line has shown that more sediment and suspended particles than can be tolerated will be present in the facility's influent water; consequently, the technical design for the new facility will call for a filtration system that will render an acoustically pure efflux. In fact, there will be three stages of filtration. The first stage will function as the initial filter for the city main water. The second stage of filtration will be the main filter, which will act to clean the water circulating in the tank. The third system will be associated with the surface-skimmer.

Later in this paper we will discuss these three filter systems in detail. For now, however, we are concerned with the overall objectives of all the filtration systems.

1-16 In general, clarification of water refers to the removal of a relatively small quantity of suspended solids from a "contaminated" source, but the clarity of any liquid is seldom absolute, even where "brilliancy" is called for. The degree of clarity is dependent upon the subsequent use of the liquid; the individual project determines the requirements. With this in mind, the first approach to any clarification should be to determine the degree of purification demanded, i.e., to determine the maximum allowable percentage of suspended solids in the filtrate. In our application, the requirement is for filtrate brilliancy, which is equivalent to optical purity. Again, we are identifying optical purity with acoustical purity for the purpose of applying the terminology usually associated with water clarification.

CORROSION

1-17 A parameter that indirectly affects the character of the water in the filtration system is the resistance of the materials in the piping to chemical and electrolytic deterioration. If there is corrosion within the filtration system itself, the scale and sediment developed in the process will be either continually circulated in the system, precipitated out in low spots in the system, or form a constriction. We have already discussed the necessity of eliminating constrictions in the piping system because of their role in generating flow noise. Figure 1-1 shows an example of what effect corrosion can have in forming a constriction in a piping system. The photograph shows an end view of a 5/8" pipe at a union, taken from a water cooler in the general location of the proposed facility. Corrosive deposits have reduced the pipe diameter by about 70% and its area by about 90% over a period of ten or twelve years. An obvious design goal for the proposed filtration system, therefore, is to prevent these detrimental effects from occurring in the piping system of the proposed facility. To accomplish this goal, it was necessary to understand something of the following concepts on the nature and causes of corrosion in order to incorporate preventative measures in the design.

a. All water coming from wells, rivers, lakes, and oceans is an extremely dilute water solution of mineral salts and gases. The salts are mineral matter dissolved by water flowing over and through the earth layers. The salts are mainly sulphates, bi-carbonates, and chlorides of calcium, sodium, and magnesium. These minerals give water its hardness and precipitate as a white lime-type scale. The dissolved gases are atmospheric oxygen and carbon-dioxide, picked up by water-atmosphere contact, e.g., spray, raindrops, and ammonia from decaying vegetable matter (reference (b)).

b. All chemical reactions require the presence of an ionizing medium. The most universal ionizing medium is water. No corrosion will occur in the total absence of water. It is to be noted that this does not mean the "apparent" absence of water. It is well-known that iron corrodes, or "rusts," very slightly in desert areas, yet some corrosion does occur, because the humidity is extremely low, but not non-existent.

c. In metal piping systems, the dissolved gases are the prime agents of chemical corrosion. The oxygen attacks the iron or steel, and the process is accelerated by carbon dioxide. The rate and extent of the chemical corrosion are influenced by the mineral salts dissolved in the water.

d. The simplest example of corrosion is that of iron in pure water. The dissolved oxygen in the water can react in either of two ways with the iron: (1) by combining with the hydrogen film to expose the surface of the iron (which the film protects), or (2) by combining with the dissolved ferrous hydroxide to form insoluble, hydrated, ferric compounds and thereby allow the formation of more ferrous hydroxide. Conversely, if the oxygen content is small, the protective hydrogen film will be relatively undisturbed and the initially high rate of corrosion will taper off rapidly (reference (e)).

e. The oxygen content of water in contact with air is a function of temperature and pressure, but in a closed piping system this is not true. If the oxygen content is lowered artificially by elevating the temperature and venting the gases released, the corrosibility of the water drops. Deaerating heaters and deaerating condensers perform precisely this function in large central steam electric generating plants. The pipe in these stations continues to corrode, but at a rate that the operators consider to be acceptable.

1-18 This completes the survey of the problem associated with the design of the filtration system. The next chapter will describe the design of the system for the proposed hydroacoustics facility; the components and configurations presented there are based on the ideas discussed in the survey of this chapter. References (f), (g), (h), and (i) contain much useful information on corrosion; these references have been used in developing the above discussion on this subject. Reference (j) and (k) have been useful as general references on filtration systems.

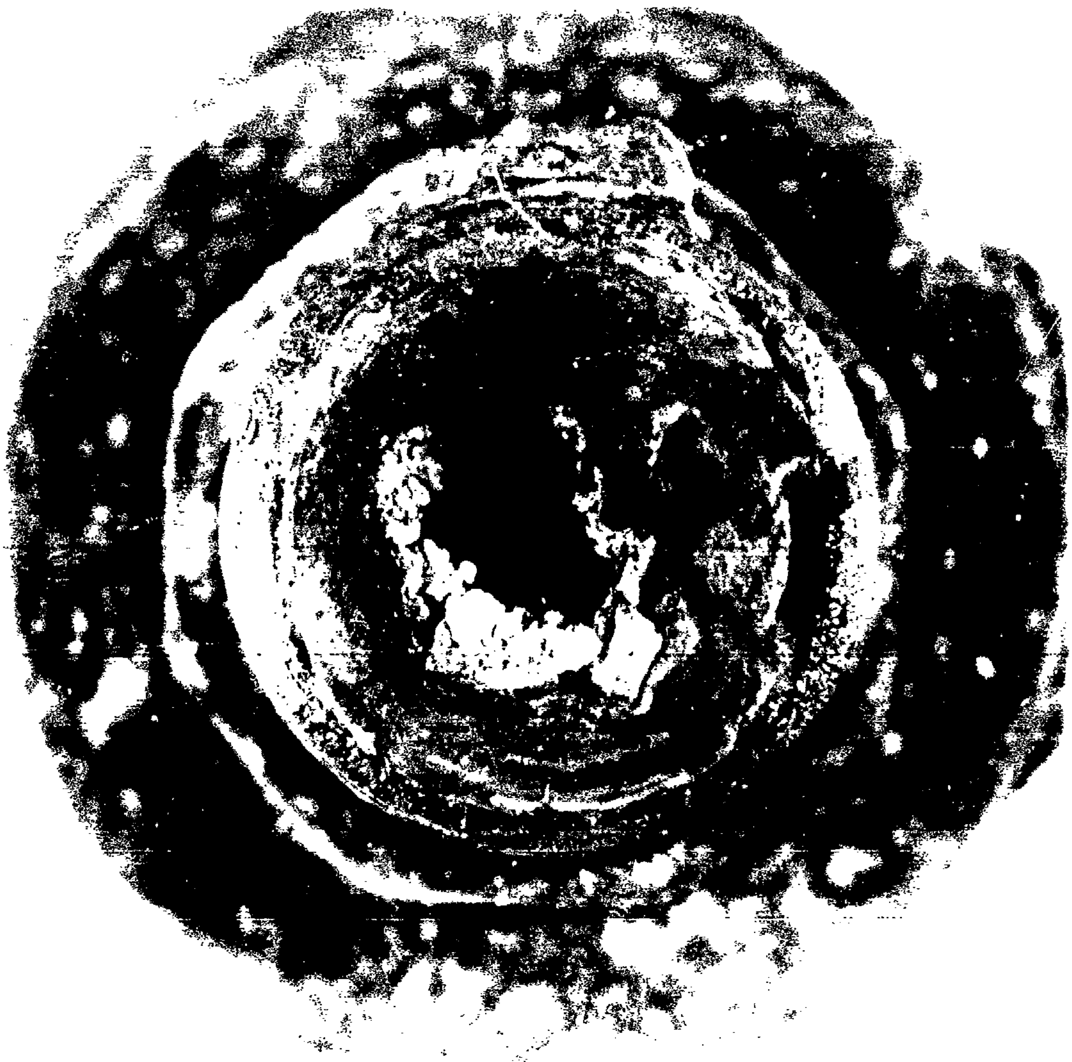


FIG. 1-1 ILLUSTRATION OF CORROSIVE EFFECTS IN METAL PIPE UNION

# Chapter 2

## The Proposed Design for the Filtration System

INTRODUCTION

2-1 The chapter discusses the design for a water filtration system; the design attempts to incorporate the major principles and considerations developed in Chapter 1. In addition to these considerations, the design presented here considers practical limitations such as on the space available for installation of the system.

2-2 The grounds for the following design proposal can be established by first stating the purpose of the filtration system:

> The purpose of the filtration system in the proposed hydroacoustic facility is to render optically pure the influent water supplied to the test facility from the municipal mains. Such optical purity, which in this case is defined as equivalent to acoustical purity, shall enable underwater acoustical investigations of high and low frequency to be conducted with negligible interference from particulate matter and air bubbles suspended in the affluent water of the filtration system. Furthermore, the filtration system must be capable of separately, but continuously, removing surface debris and of conditioning newly admitted water to a clarity and temperature that will not affect the results of acoustic tests being performed in the testing tank; this must be accomplished with only infrequent minor maintenance procedures. The system must only include materials chosen for their corrosive resistance and compatibility with other materials in the system; all components must be selected and mounted so as to reduce to an acceptable level all noise and vibration associated with operation of the filtration system.

2-3 The proposed filtration system design may be considered as several subsystems, each of which has a special function. First, the testing tank itself holds the filtered water in which underwater acoustical devices will be tested. The main circulation loop is the path by which the main pump continuously circulates the water in the testing tank through a diatomaceous earth filter. The replenish subsystem is the route by which new water is brought into the system to replace water that has been lost through evaporation or leakage. The skimmer subsystem continuously filters the water in the top 1/16th of an inch of the testing tank to remove floating debris, such as airborne dust. The control subsystem furnishes automatic and remote control capabilities for safety and convenience in operating the filtration system. Let us now consider each of these subsystems in detail.

THE TESTING TANK

2-4 References (a), (l) and (m) discuss some of the geometric and acoustic requirements for the water filled volume in which the hydroacoustic tests will be conducted. These requirements primarily relate to the selection of a tank that makes possible the measurement of the "far field" properties of acoustic transducers, i.e., those acoustic properties that have influence beyond a critical distance from the acoustic center of the transducer (reference (l)). Reference (l) also discusses the effect of reverberation time on acoustic testing and concludes that the reverberation time in a wooden testing tank would have a negligible effect on the results desired from the proposed facility.

2-5 To be of use in a wide variety of underwater acoustic investigations, the testing tank for the proposed hydroacoustic test facility should be a right circular cylinder approximately 30 feet in diameter by 20 feet deep; such a tank which could hold 102,000 gallons of water, was the size used for the filtration system design presented here. This tank should be made of cypress because of its durability, its resistance to swelling, shrinkage and rot, and because it gives no color or odor to water. (Douglas fir and California redwood cost less and have many of the qualities of cypress for water, but they are not as durable.)

2-6 Figure 2-1 shows a schematic diagram of the complete proposed filtration system. That figure shows the main circulation loop, the replenish subsystem and the skimmer subsystem connected to each other, to the city main and to the testing tank. To facilitate the detailed discussion of each of these plumbing subsystems, however, we shall consider each one separately and with a schematic diagram for each subsystem.

MAIN CIRCULATION LOOP

2-7 The purpose of the main circulation loop is to continuously circulate the water in the testing tank through diatomaceous earth filter, as indicated in Figure 2-2. This process is necessary to maintain a high degree of clarity and, therefore, acoustical purity.

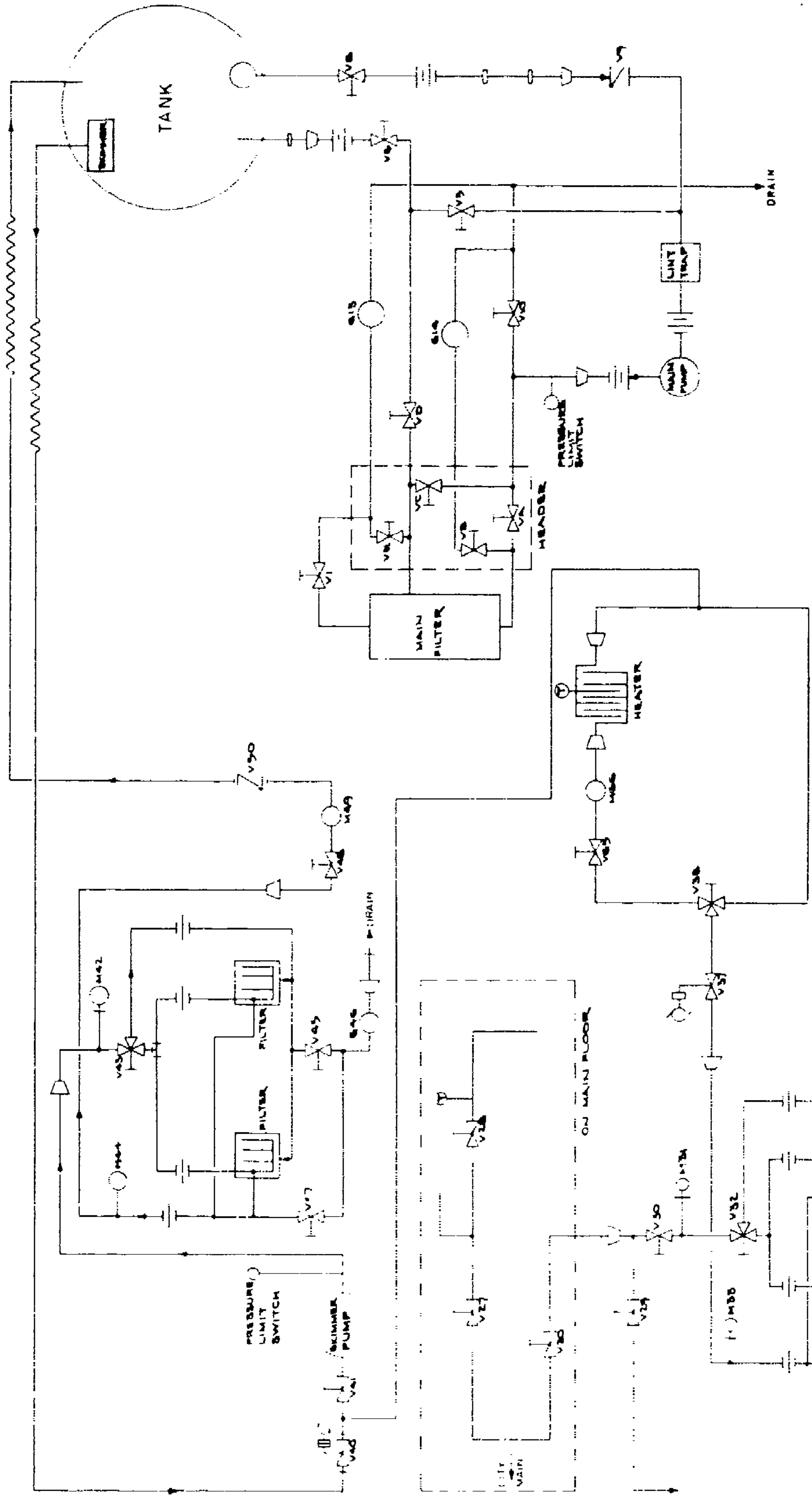
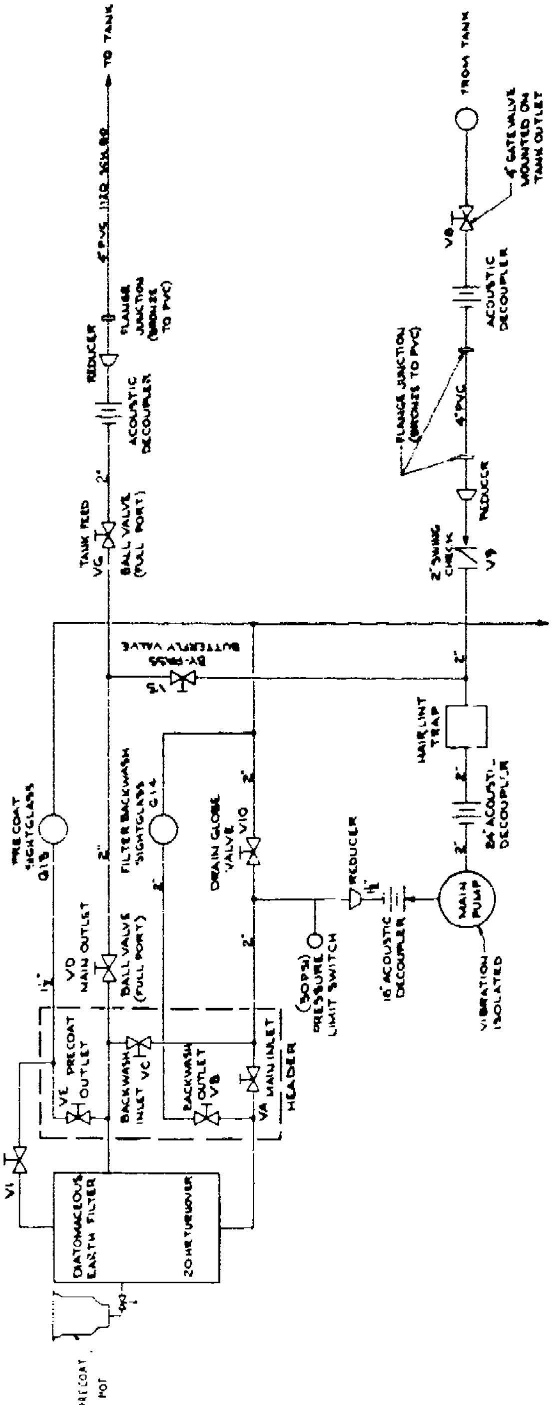



FIG. 2-1 SCHEMATIC DIAGRAM COMPLETE FILTRATION SYSTEM



NOTES
1. UNLESS OTHERWISE INDICATED, PIPES ARE TO BE BRONZE.
2. ALL PVC PIPING TO BE PVC 1120, SCHEDULE 80.
3. ALL COMPONENTS IN HEADER SHOULD BE INTERNALLY COATED WITH CORROSION RESISTANT EPOXY

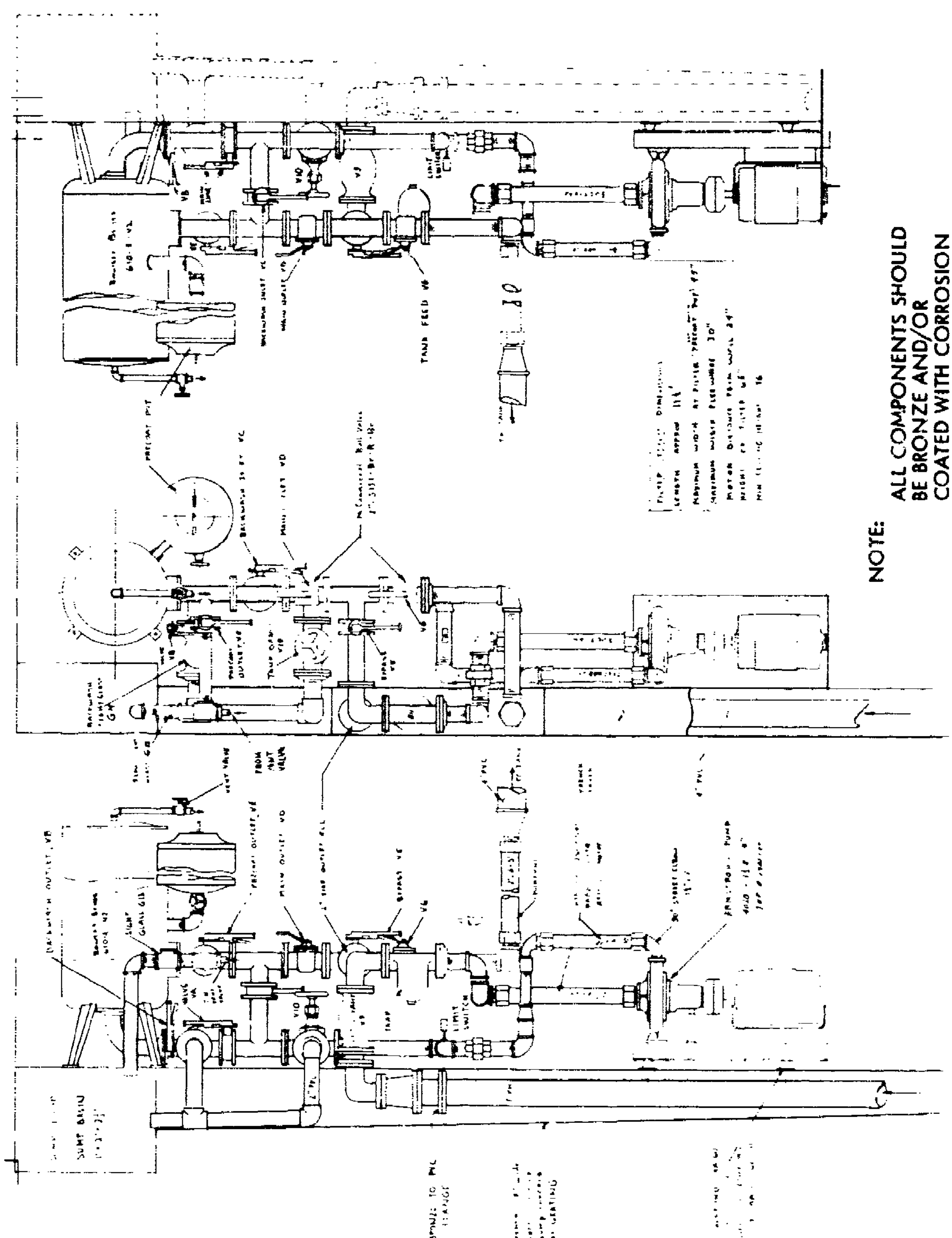
FIG. 2-2 SCHEMATIC DIAGRAM OF MAIN CIRCULATION LOOP

Unclear water would indicate the presence of suspended particulate matter or bubbles that could cause erroneous results in high frequency tests conducted in such water.

2-8 The main pump furnishes the motive energy for moving the water from the testing tank, through the filter and back into the tank.

2-9 Water will leave the main tank through a flanged boltless bronze connector flush mounted at the bottom of the vertical side of the wooden testing tank. A four-inch bronze gate valve (V-8), flange-mounted on the outside of the connector, will serve as a shut-off valve to hold the water in the tank if it is necessary to open the filtration system for repairs. This valve is necessary because significant damage to the wooden tank could result from its evacuation after its sides have swollen and sealed due to the absorption of water. From this valve, the water will flow down through a long radius "S" to a four-inch PVC pipe in a floor trench, which leads to the filtration room. An acoustic decoupler, 24 inches long, will be inserted into this four-inch pipe to reduce the transmission of noise and vibrations from the piping system back up into the wooden walls of the test tank. The trench in which the four-inch PVC pipe and acoustic decoupler are placed will be eight inches wide with a bottom sloped to a sump basin; this trench will be covered by a grating. Figure 2-3 shows a plan view and side views of the main circulation loop; the side views indicate the position of the four-inch PVC pipe in the sloped trench. At the end of the four-inch PVC pipe, a flanged reducer funnels the water into a two-inch line and a two-inch bronze flanged swing check valve (V-9). This check valve is necessary to prevent a reversed flow of water <u>into</u> the testing tank outlet during the by-pass operation, which will be described later. A two-inch line leads from the swing check valve to one side of a two-inch flanged bronze side outlet ell. The other two outlets of the ell connect to the by-pass line and to a flanged bronze hair and lint trap, which will screen out foreign objects such as buttons, coins, and rocks inadvertently dropped into the testing tank. This trap is a protective device for the impeller of the main circulation pump.

2-10 After the water from the testing tank passes through the hair and lint trap, it will be drawn into the suction side of the main circulation pump through a two-foot long acoustic decoupler. Both this decoupler and its companion on the discharge side of the pump must be mounted parallel with the axis of the motor that drives the pump; these decouplers will screw into the suction and discharge nozzles. The purpose of the decouplers is to diminish the transmission of the turbulent noise produced in the pump by action of the impeller on the water.



NOTE: ALL COMPONENTS SHOULD BE BRONZE AND/OR COATED WITH CORROSION RESISTANT EPOXY.

FIG. 2-3 SIDE AND PLAN VIEWS OF MAIN CIRCULATION LOOP

2-11 Since the main circulation pump will be the primary source of noise in the system, every precaution must be taken to minimize all the noise generated by it. These precautions will consist not only of the acoustic decouplers in the flow lines, but will also include vibration isolation mountings for the pump and motor, and the use of sleeve bearings in the pump. The pump will be a centrifugal pump with eight-inch diameter impeller powered by a three horsepower, 1750 rpm motor. The volute, impeller and sleeve bearings will be made of bronze and other parts of the pump will be constructed of materials that will be compatible with bronze and that will assure long life and quiet operation of the pump. The power requirements for the pump motor are determined from the calculations given in Appendix A. The 18-inch long acoustic decoupler in the discharge line will be one and one-half inches in diameter; it will connect with a reversed reducer that will increase the pipe size back to two inches. A pressure limit switch will be inserted into the pipe leaving the reducer. This switch will be adjusted so that a pressure of 30 psi will cause the main pump to stop and remain stopped until its motor starter has been manually reset. From this point the water may be directed either to the drain or to the main filter. If it is to go to the drain, the two-inch flanged bronze tank drain globe valve (V-10) would be open and the butterfly valve (VA), the main inlet to the filter, would be closed. A globe is desirable as the tank drain valve because of its capability to regulate flow during a required draining operation and because of its no leakage, positive sealing capability. (A leakage through this valve would go unnoticed and would needlessly waste filtered water.) In normal operation, however, the tank drain valve (V-10) will be closed and valve VA open so that the water from the testing tank may be circulated through the main filter.

THE MAIN DIATOMACEOUS EARTH FILTER. Valves VA, VB, VC, VD, and VE and their interconnecting pipes form the "header" for the main filter and are usually supplied as integral part of the filter. Valves VA, VB, and VC will be two inch, double-ribbed, bronze butterfly valves that use an O-ring in the disc for positive sealing; valve VE shall be a one and one-half inch, identical butterfly valve. These valves should have seats molded from a reinforced polyester resin for corrosion and abrasion resistance. Each of these valves will be equipped with a manual operator arm that can be secured in open and closed positions. Valve VD will be a two inch, bronze, flanged, full-port ball valve; the seat and seal of this valve should be a resilient, corrosion-resistant material such as TFE (tetrafluoroethylene). All the water from the filter will flow through this valve (VD), which is the main outlet of the filter. This valve will be a full-port ball valve to provide on-off operation with a minimum amount of interference to the fluid flow. The valves in the header shall be identified as follows: VA is the main inlet valve, VB is the backwash outlet, VC is the backwash inlet, VD is the main filter outlet, and VE is the outlet for the precoat operation, which will be discussed later.

2-12 The main filter for the filtration system will use diatomaceous earth as the primary filtering medium. During a coating process, this powered medium will be made into a slurry in a precoat-pot attached to and supplied with the filter; the slurry will be deposited upon the core elements inside the main filtration tank. These core elements will consist of 36-inch long, rigid, porous nylon bag upon which the diatomaceous earth medium will be deposited.

2-13 The main filter will have the capacity for a 20 hour "turnover" of the water in the testing tank at a flow rate of about 85 gpm; i.e., there should be enough filtering area so that, under routine operations, about 102,000 gallons of water may be processed through the filtration system every 20 hours. (This is a much slower turnover rate than is recommended for comparably sized swimming pools, but the hydroacoustic facility will not be subjected to the same contamination loading rate as would the swimming pool.) The desired advantage gained from this slower turnover is in the greatly reduced flow noise due to a reduced flow velocity through the pipes and valves of the system. Another advantage gained is in the reduced size of filter, pipes and valves needed in the system.

2-14 The gravity type precoat-pot supplied with the filter will have quick-opening bolt closures on a lever-lifted cover, and a complete set of individually mounted and bag-covered filter elements. The cover will contain a vent valve to provide for air escape during filling. The exteriors and interiors of the filter chamber and the header components and piping should be finish-coated with a corrosion proof coal tar epoxy. The filter should be supplied with an external view port for observing the elements, and inlet and outlet pressure gauges; the complete filter header combination should be able to withstand a 150 psig hydrostatic test. The maximum height required for removal of the elements cannot exceed 100 inches.

2-15 The backwash outlet valve (VB) will be connected to the drain through a two-inch line. A filter backwash sight glass (G-14) will be mounted in that line for observation of the backwash so the operator can know when the filters are clean.

2-16 The precoat outlet (VE) will be similarly connected to the drain through a one and one-half inch line and a precoat sight glass (G-13). Through this sight glass, the operator will be able to determine that all newly introduced diatomaceous earth has been deposited on the filter elements and that none of it is traversing the bag and core material, i.e., coming out in the filtrate.

2-17 The backwash inlet (VC) will be operated only when all the valves in the header except the backwash outlet (VB) are closed. This valve will admit water coming from the main pump into the center of the filter elements; this will cause the nylon bags over the filter elements to balloon out and the diatomaceous earth cake to be dispensed into the water in the main volume of the filter tank. This water will travel through the open backwash outlet (VB) to the drain.

2-18 The main outlet (VD) will be connected through a two-inch line to a by-pass butterfly valve (V-5) and to the tank feed valve (V-6). The by-pass valve will be used to divert water from the tank feed and send it back to the pump and through the filter. This will be used to stop flow noise associated with water entering the test tank while, at the same time, maintaining pressure in the main filter; the tank feed valve (V-6) will be closed during this operation (V-6 will be a two-inch flanged, bronze, full-port ball valve with resilient seat and seal, identical to valve VD already described). Such an arrangement is desirable because, when the flow of water through the filter is stopped, the diatomaceous earth cake will slide off and be deposited in the bottom of the filter tank. When water flow is resumed after such a stoppage, much of the old diatomaceous earth will be redeposited on the nylon bag. But where contaminant particles previously have been primarily confined to the surface of the cake, they will now be interspersed in the new cake and will be in contact with the nylon bag, which is more porous than the diatomaceous earth filter cake. The resulting filter cake is not as efficient as the initial one, and in fact, will tend to allow contaminants to pass through with the filtrate. Because of this situation, it will usually be advisable to backwash the filter and apply a new coating of diatomaceous earth after any interruption of the flow through the filter. During a test where pump noise and flow noise inside the filtration room would not interfere with the test in the wooden tank, the by-pass valve (V-5) can be opened and the tank feed valve (V-6) closed. This will maintain the necessary flow through the filter to keep the diatomaceous earth cake on the nylon bags of the filter elements and eliminate the flow noise at the tank inlet. If the filtration room noises interfere with the acoustic test, however, the pump will have to be stopped and the precoating operation performed before re-instituting the filtration cycle. To supplement the system description given here, Appendix B includes the explicit details of the precoat, normal operation, and by-pass procedures for the filtration system.

2-19 In routine operation, the tank feed valve (V-6) will be open and newly filtered water will flow through V-6 into a two-inch line that contains an 18-inch long acoustic decoupler section similar to that in the outlet from the tank. After the acoustic decoupler, the line will contain a reversed reducer to increase the line size from two-inches to four inches; the four-inch side will connect with a four-inch PVC pipe that carries the filtered water back to the top of the wooden tank. At the lip of the tank, the PVC pipe will connect to two long-radius, 90 degree elbows or street ells joined to form an inverted "U"; this will direct the flow downward into the tank. The "U" formed by these elbows will be supported from the ceiling by an elastomeric vibration isolating pipe hanger. The "U" will terminate in a flange to which various nozzles will be attached in an experimental determination of a length and shape that will minimize the turbulence and flow noise associated with the entry of the filtered water into the testing tank.

THE SKIMMER SUBSYSTEM

2-20 The purpose of the skimmer subsystem is to continuously and independently filter the surface of water in the wooden testing tank. The need for this is evident when one realizes that the upper surface of the water is the primary interface between the "Clean" and the "Dirty" environment associated with the filtration system. Experience with swimming pools, ponds, etc. has adequately demonstrated that, even with no swimmer load, the surface of an exposed body of water accumulates a substantial load of dust and debris. Of course, the water surface in the hydroacoustics facility will not be exposed to a natural unprotected environment, but there is the obvious possibility of surface contamination such as by floor dust from above and by hair and lint from operators working over the surface. Ideally, then, the skimmer subsystem will remove the major portion of the externally introduced contaminants. Independence for the skimmer subsystem is desirable to diminish the loading and consequent necessity for backwashing the main filter.

2-21 The surface skimmer itself, herein referred to as the skimmer head, shall consist of a molded elastomeric housing. The base shall incorporate two ½-inch I.P.S. threaded apertures which will serve as the external pipe connections to a pump. The skimmer head must be capable of handling flow rates between 25 and 50 gpm. It shall be supplied with a deck plate for easy access to the skimmer interior.

2-22 The skimmer throat should have an integral molded hinged weir stop with a cushion attached; it should automatically adjust to variations in water level within a four-inch range. A removable synthetic debris basket must be provided in the skimmer body.

2-23 In the normal skimming operation the pump attached to the skimmer head outlet draws water from the body of the skimmer and causes surface water from the main part of the tank to rush in over the lip of the floating weir. This action carries all floating hair, bugs, etc., into the skimmer to be trapped in the strainer basket. Dust and other fine particles pass through the strainer to be removed by the filter. A valve plate mounted on the inside of the skimmer, adjusts the flow rate to the desired valve between 25 and 50 gpm.

2-24 The use of the skimmer will be treated experimentally to determine its most efficient positioning with respect to the main water inlet to the tank. Because of this experimental nature, the skimmer head will be mounted using brackets and clamps developed experimentally as required.

2-25 The two-inch skimmer outlet will be connected to a 20 to 30 foot long, one and one-half inch i.d. vinyl reinforced flexible hose that carries the water from the skimmer head to the filtration room. To allow for portability and the experimental nature of this subsystem, the hose will be supported 10 to 15 feet back from the skimmer head by a rope tied from the ceiling of the basement. From that point, the hose will drop vertically downward about 10 feet to a coupling at the end of a two-inch PVC pipe coming horizonally off the top of the filtration room. In addition to the flexibility offered by this arrangement, the hose will serve as an acoustical decoupler between the skimmer head and the vibration and flow noise associated with the skimmer pump and the filtration room.

2-26 Figure 2-4, a schematic diagram of the skimmer subsystem, shows the flexible hose from the skimmer head connected to a long one and one-half inch PVC pipe. This pipe will run horizontally across the roof of the filtration room and down into it to connect with an automatically operated valve (V-40). This valve will be a one and one-half inch, flanged, bronze, full-port ball valve operated by a 250 lb-inch torque electric actuator from switches both at the pump and on the main floor of the facility. (NOTE: For reasons described below, this valve (V-40) will be wired in parallel with valve V-37 in the replenish subsystem; V-40 will be open when V-37 is closed.) The purpose of V-40 is to interrupt flow from the skimmer head when water is being added to the system through the replenish subsystem. The manually operated valve, V-41, a screwed, bronze, full-port ball valve, will serve as the inlet valve to the skimmer pump. This valve will only be closed for maintenance work on the pump and on the filter. (An operator will have to be diligent in his attention when starting the skimmer pump -- he must be sure that V-41 is open before starting the pump.)

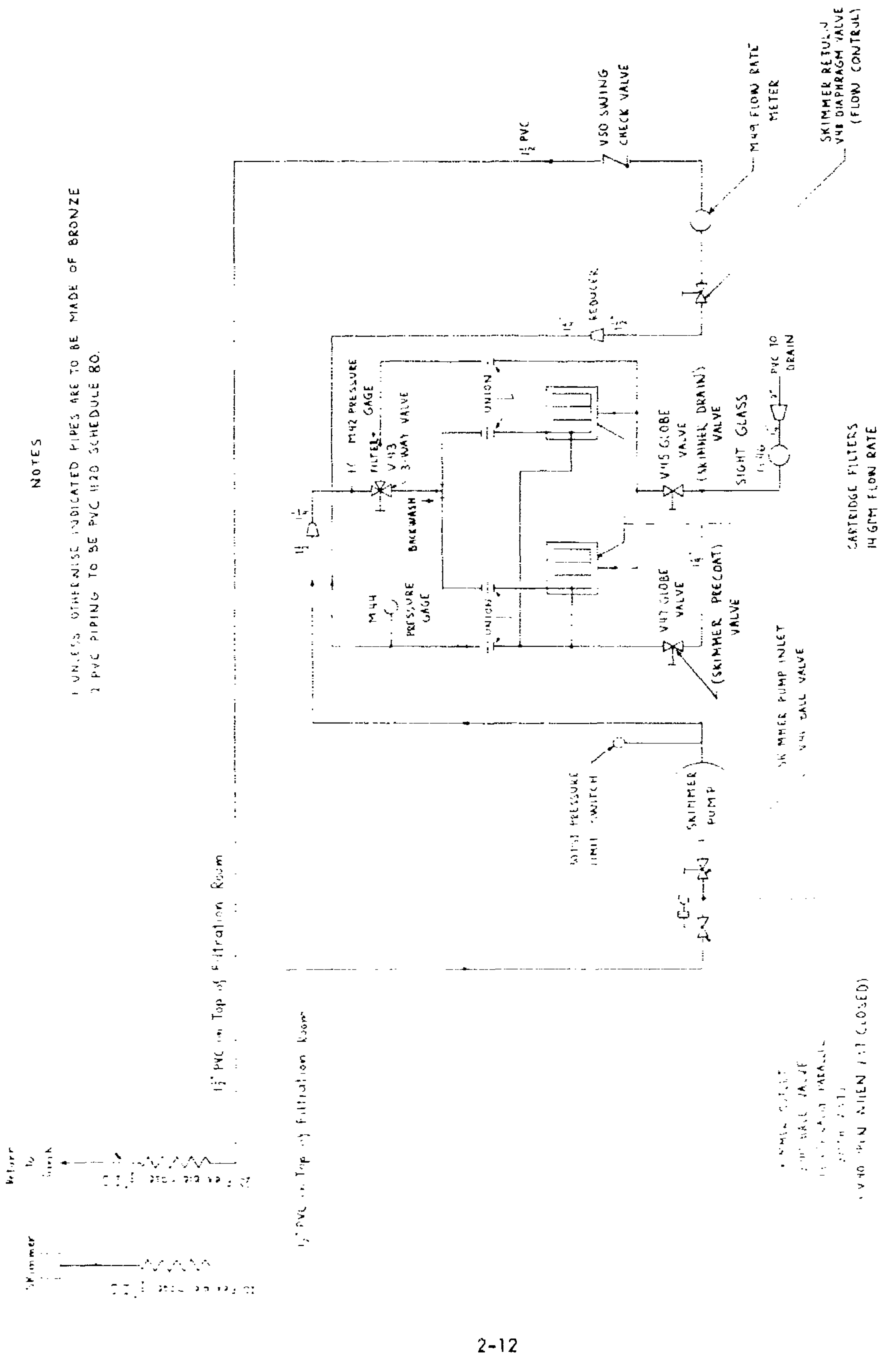



FIG. 2-4 SCHEMATIC DIAGRAM OF SKIMMER SUBSYSTEM

2-27 The skimmer pump will have two functions:

a. It will pump water from the water surface of the testing tank, through the skimmer head, through the skimmer filters, and back to the top of the testing tank; and

b. It will supply the motive energy for the new water added to the system through the replenish subsystem. The skimmer pump will be required to have a capacity of about 28 gpm, and be driven by a one and one-half horsepower motor. Because the skimmer will admit air along with the surface water, the impeller will be exposed to large amounts of air in its pumped fluid. A centrifugal pump would cavitate under these conditions and is therefore not recommended in this application. A small self-priming rotary pump could satisfy the pumping requirements of the skimmer except for the fact that the skimmer pump would be expected to operate continuously; even though this type of rotary pump is frequently used in swimming pool skimmer systems, it is not recommended for the hydroacoustics facility application. One pump that is self-priming, noncavitating, and continuously operable is the type called "Snore-Pump," a miner's expression for a pump that can continuously suck up a mixture of air and liquid. This concept of pump performance surpasses the ability of a pump to self-prime with a fully submerged suction entry. This type of performance is available in a pump using a sliding-shoe design in which the pumping action is derived from the rotation of eccentric discs that fit closely into plastic displacement chambers or shoes. The eccentric discs reciprocate horizontally to make the shoes reciprocate vertically. The delivery from each shoe is intermittent, but a combination of three or more shoes gives a smooth, continuous discharge. Such "Snore-Pumps" are used in clearing out dirty water and oil from sumps, for pumping the bilges of ships, for extracting condensate from gas mains, and for boosting water pressure in ships and buildings. Pumps of this type usually use sealed ball bearings that are lubricated for life; these bearings are usually noisier than sleeve bearings. In the acoustic facility, however, the skimmer pump may be stopped for quiet tests, a fact that makes the use of ball bearings in the skimmer pump acceptable. Also, these pumps may either be direct coupled to the driving motor or they may use a V-belt drive. For use in the hydroacoustic facility, either drive method could be used, but a V-belt drive is recommended to allow for greater flexibility in adjusting the speed of the pump to match it to the capacity requirements of the skimmer subsystem. The pump recommended for use in the skimmer subsystem, therefore, should be a sliding-shoe pump with a bronze body, stainless steel port plate, a rotor of some corrosive resistant steel alloy, and synthetic rubber shoes. The pump should be supplied with a V-belt drive motor matched to the requirements of the skimmer subsystem; these requirements include quiet operation, a maximum of 65 feet of discharge head, and a capacity of 28 gpm. The suction and discharge ports of the pump should have one and one-half inch screwed fittings, with the suction port linked to V-41 through a short bronze one and one-half inch pipe. A pressure limiting switch will be installed in the discharge line of the pump. This switch will be set to interrupt the power to the skimmer pump if the pressure in the discharge line reaches 30 psi. The switch should require manual resetting to restart the pump so that an operator will be required to inspect the skimmer filter and its valves to determine the cause of the pressure switch actuation.

2-28 From the skimmer pump and the pressure limiting switch, a one and one-half inch bronze pipe will connect to a one and one-quarter inch line through a reducing coupling and will direct water to the skimmer filter. A pressure gauge (M-42) will measure the pressure of the water entering the filter at its three-way entrance valve (V-43). The three-way valve will either direct water into the body of the filter tank for filtration or it will direct water into the filter cartridges for backwashing. The filter body will consist of two small diatomaceous earth cartridge filters connected in parallel as shown in Figure 2-4 to provide double the filtering area of each one alone. These filters will use disposable cartridge elements made of round, thin, cellulose impregnated with a synthetic resin. These filters will have a built-in precoat pot and internal flow path connections so that a diatomaceous earth filtration medium may be used to coat the cartridges for finer filtrations than that afforded by the cartridges alone. Such an arrangement will provide a high level of filtration versatility for the skimmer subsystem. In routine operation, these filters can be treated just as the main filter, requiring periodic backwashing and precoating. When conditions require that the skimmer be shut off during acoustic testing, the diatomaceous earth medium can be removed by backwashing and the skimmer subsystem started and stopped at will, using only the cartridges as the filtration medium. Experience with this system may indicate that the cartridge filtration alone is sufficient and that the diatomaceous earth medium is not necessary.

2-29 The two small cartridge filters used in the skimmer subsystem should be steel cylinders of an all-welded construction about eight inches in diameter and 45 inches tall. They should be coated internally with a corrosion resistant epoxy. They should have a bolt-down cover that can be easily and quickly removed for access to the cartridge elements; each cylinder should hold four filter cartridges. The manifold connecting the filters in parallel will consist of bronze one and one-quarter inch piping, valves, gauges, and sight glass as is indicated in Figure 2-4. The globe valve V-45 is the drain valve, used during the backwash operation to admit the contaminated diatomaceous earth to the drain. The operator will observe the clarity of the backwash through sight glass G-46. The globe valve V-47 will be used immediately following the precoating operation to let the operator be assured that no diatomaceous earth is bleeding through the cartridges into the filtrate; by using V-47, he will be able to observe the filtrate through G-46 until its clarity is acceptable.

2-30 The need for two filters in the skimmer subsystem is determined by the capacity of the skimmer head and of the type of filter desired. Since the skimmer head recommended above has a capacity range of 25 to 55 gpm, the filter must also be able to handle that capacity. But we have just presented arguments that point out the versatility of cartridge filters. Therefore, because each of the cartridge filters under consideration has a capacity of 14 gpm, two of them in parallel will be needed to furnish a 28 gpm capacity, which is commensurate with the capacity of the skimmer head.

2-31 After the water passes through the filter, a gauge (M-44) will monitor the discharge pressure. The maximum allowable pressure differential between the value shown on this gauge and that on gauge M-42 is 20 psi; i.e., the operator should backwash or replace the cartridge elements before these gauges show a 20 psi pressure differential. Beyond the pressure gauge M-44, the filtered water will flow through a one and one-quarter inch pipe, a one and one-half inch pipe, and then to the skimmer return flow control valve V-48. This valve will be a one and one-half inch screwed, straight way diaphragm valve with a bronze body and solid TFE diaphragm. The purpose of this valve will be to regulate the flow rate of the skimmer subsystem and to function as a system shut off if needed during a backwash operation. It is expected that this valve will normally remain in one position and will not have to be closed or opened once it is initially set to adjust the flow rate. The presence of this valve is necessary in the system however, because the skimmer head and skimmer pump described above will have greater capacities than should be handled by the filters. The purpose of valve V-48, then, is to establish a flow in the system commensurate with the capacity of the filters. The flow rate will be easily determined by the operators reading the flow rate meter (M-49) that will be connected to the discharge side of V-48. This flow rate meter should be the type that can be inserted into the flow line at any point by penetrating the flow line. The scale on the flow rate meter should be able to indicate capacities from about 5 to about 40 gpm.

2-32 From the flow rate meter, the filtered water will flow into a vertical one and one-half inch PVC line mounted on the wall of the filtration room. At about head height, this line will be interrupted with a flanged or wafer type swing check valve (V-50). This valve should have a bronze body and a renewable disc made of some pliable dense, durable composition. The purpose of this valve will be to prevent water siphoning back through the skimmer return line during maintenance operations on the filters. On the discharge side of this valve, a one and one-half inch PVC line will direct the filtered water through the top of the filtration room and in a horizontal direction to a point where, like the skimmer inlet line, a one and one-half inch flexible hose will connect to return the water to the top of the testing tank. The type and placement of the discharge nozzle on the flexible hose will be determined experimentally using criteria of minimizing turbulence, noise and air bubbles. Because the skimmer head and pump will inherently mix air with the water being filtered, it will be desirable to keep the skimmer return water confined to a top layer of the testing tank. This will help maintain the air content homogeneity of the water at the testing depth.

THE REPLENISH SUBSYSTEM

2-33 Figure 2-5 shows the replenish subsystem for the filtration system. The purpose of this subsystem is to furnish a path through which new water can be added to the system when evaporation or leakage has caused a loss. This is also the path through which the testing tank will be filled initially. The supply line from the municipal water main will be one and one-half inches as required by the applicable codes. This one and one-half inch line will enter the building on the first floor and will feed two parallel one and one-half inch screwed bronze globe valves (V-20 and V-47), also on the main floor of the facility. Because the water line pressure near the location proposed for the hydroacoustic facility is about 55 psi, these valves admitting water from the municipal main should have 125 to 150 pounds steam pressure ratings, which is equivalent to 200 to 225 pounds non-shock cold water pressure rating. This same range of pressure rating should be applicable for all fittings and components in the filtration system. Valve V-27 will control the water supplied to the usual plumbing facilities of the hydroacoustics facility; e.g., toilets, sinks, water coolers, etc. In this branch will be a one and one-half inch line with another globe valve (V-28) and an in-line thermometer inserted through an appropriate bushing and nipple. This special line will terminate at a transducer wash station that will consist of a sunken drain outlet below a four foot by four foot floor level grating. There are two purposes for this arrangement: (1) By viewing the clarity of the water at this point, an operator will be able to purge the supply line before admitting

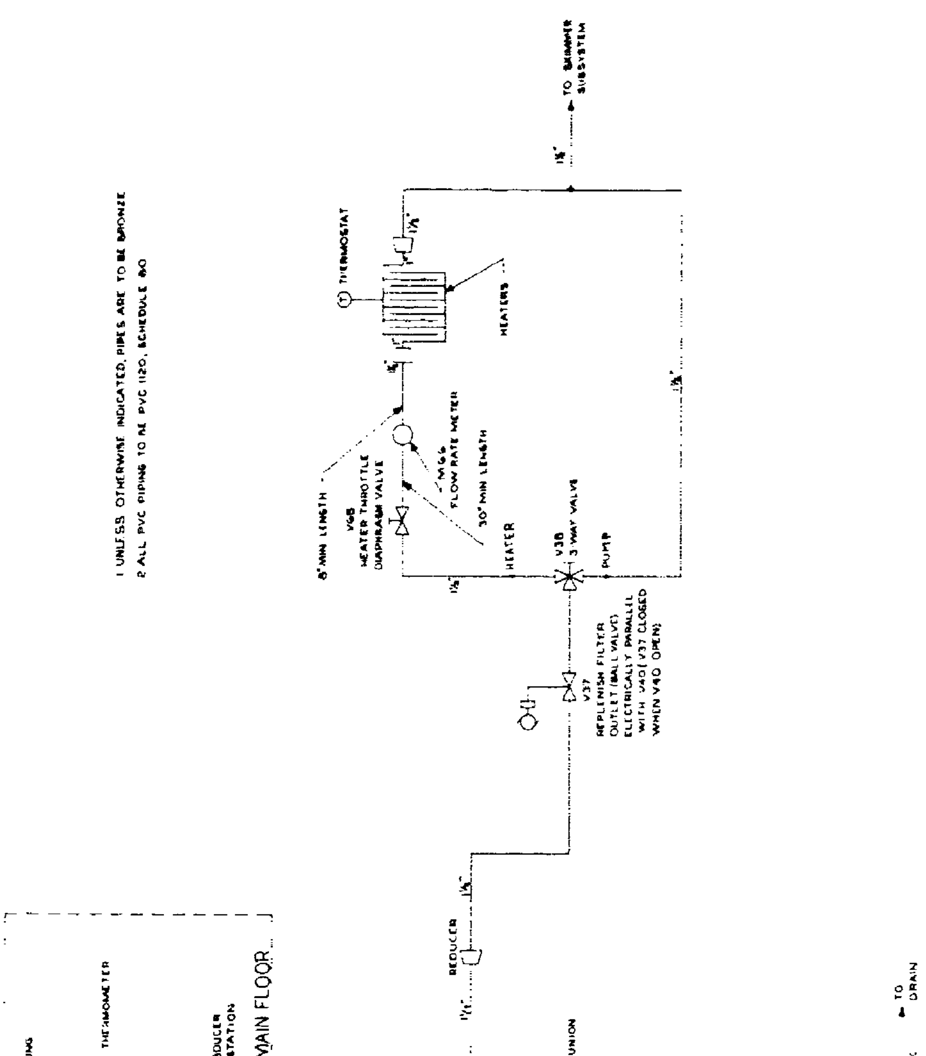



FIG. 2-5 SCHEMATIC DIAGRAM OF REPLENISH SUBSYSTEM

new water into the replenish filter in order to help reduce the load on the replenish filters; and (2) the transducer wash station will furnish a definite place at which transducers and other components can be thoroughly cleaned before being placed into the testing tank. This is another attempt to keep the testing tank clean and to reduce the load on the main filter system. The thermometer will let the operator determine the temperature of the incoming water, a fact that will be important for adjustment of the heater described below.

2-34 In the other piping branch from the municipal main, V-20 will control the water flow going to the filtration system; this valve will be located on the main floor of the facility, but the discharge line from it will penetrate the floor in a vertical run down to the filtration room. The pipe in this vertical run may be PVC but, because we prefer not to use PVC at screwed junctions, a one and one-half inch bronze screwed pipe should be attached to V-20 and run through the floor, where it would terminate in a flange. At this flange, a one and one-half inch PVC pipe could complete the flow path down to the filtration room. In the filtration room, the PVC pipe will connect with a one and one-half inch to one and one-quarter inch reducer then with a hose bibb (V-29) and the inlet valve to the replenish filters (V-30). The hose bibb will supply water for washing down the filtration room and the filters if that becomes necessary. The one and one-quarter inch flanged bronze inlet globe valve (V-30) will be in series with V-20; this redundancy provides flow interrupting capabilities both in the filtration room and on the main floor of the facility. Normally, V-20 will be used to interrupt the source of new water because of its proximity to the purging valve (V-28). Beyond V-30, the replenish filter will be identical with the skimmer filter described above; Figure 2-5 includes a schematic diagram of this filter with its valves named and numbered. The pressure differential between the values on the filter inlet and outlet pressure gauges must not exceed 20 psi; the system operator should either backwash these filters or replace the disposable cartridges when the pressure differential nears 20 psi. The operation of the replenish filter will be identical with the operation of the skimmer filter. Appendix B gives the details of operation.

2-35 At the discharge side of the replenish filter, valve V-37 will start and stop the flow as required and called by the operator. This valve, which will normally be closed, will be controlled by a 250 lb-inch torque electric actuator wired in parallel with the actuator of valve V-40 in the skimmer subsystem. Upon actuation, V-37 will open and V-40 will close to expose the water in the replenish subsystem filters to the suction of the skimmer pump. By choice of the operator, the three-way valve V-38 will direct this water either directly to the skimmer pump or will divert it through a heater. The three-way valve will be bronze with screwed connections and the seat will be made of some elastomer. Normally, this valve will be positioned to send the replenish water directly to the pump through a one and one-half inch bronze pipe. At certain times during the winter, however, it will be advantageous to warm the incoming water before introducing it to the testing tank. To accomplish this the three-way valve will be changed to divert the replenish water to V-65, a one and one-half inch bronze screwed solid TFE diaphragm valve used to control the flow rate into the heater. Meter M-66, a pipe penetration type flow rate meter, will measure the rate governed by V-65.

2-36 The need for a heater is anticipated on the basis of data obtained from the Washington Suburban Sanitary Commission on the range of water temperature available to the Laboratory. WSSC records show that the water temperature in the vicinity of the Laboratory has varied from about 37°F to about 78°F in the course of a year. Since the desired operating temperature of water in the testing tank is about 72°F, it is clear that it will be necessary to heat replenish water when the temperature of the incoming water is so low that ordinary mixing will not equalize the temperature within a short time of its introduction into the testing tank. To accomplish this heating, a heater that can warm water as it flows into the system will be needed. An 18 or 20 kw heater would be acceptable on the basis of a minimum flow rate of about four gpm at about 40°F or a 28 gpm flow rate around 67°F. The reasons that these values are acceptable are: (1) at the minimum temperature of about 40°F, it still will be necessary to supply the replenish water to the pump at a rate sufficient to keep it from pumping air only. This would not damage the pump specified earlier, but it would tend to increase the amount of air suspended in the upper layer of the testing tank. (2) Since the capacity of the filters and the pump are to be designed around 28 gpm, it is recommended that the heater be capable of handling approximately this capacity at 67°F, which is a nominal "average" temperature for the incoming water during the summer months. Above 67°, the heater will probably not be required because the incoming water temperature will quickly be equalized by the larger temperature reservoir inherent in the body of water in the testing tank.

2-37 The 20 kw heater should have two three-phase circuits available at 208 volts. The heating structure should consist of three immersion heaters of two elements each mounted through a head of a heavy steel vessel sized in accordance with ASME standards. The vessel must be designed for 100 psig working pressure and 200°F working temperature. It should be insulated with at least two inches of fiberglass. The heater must be supplied with a pilot-duty, built-in indicating thermostat having a 50 to 250°F temperature range; this thermostat must have an inherent sensitivity of plus or minus 1°F. Each circuit should be supplied with a magnetic contacter actuated by the thermostat switch.

2-38 The use of the heater will be determined experimentally. A possible use beyond just providing 72°F water will be to warm water above 72°F so that it would tend to remain in the surface layer of the testing tank; this would allow some time for trapped air to escape from the incoming air saturated water.

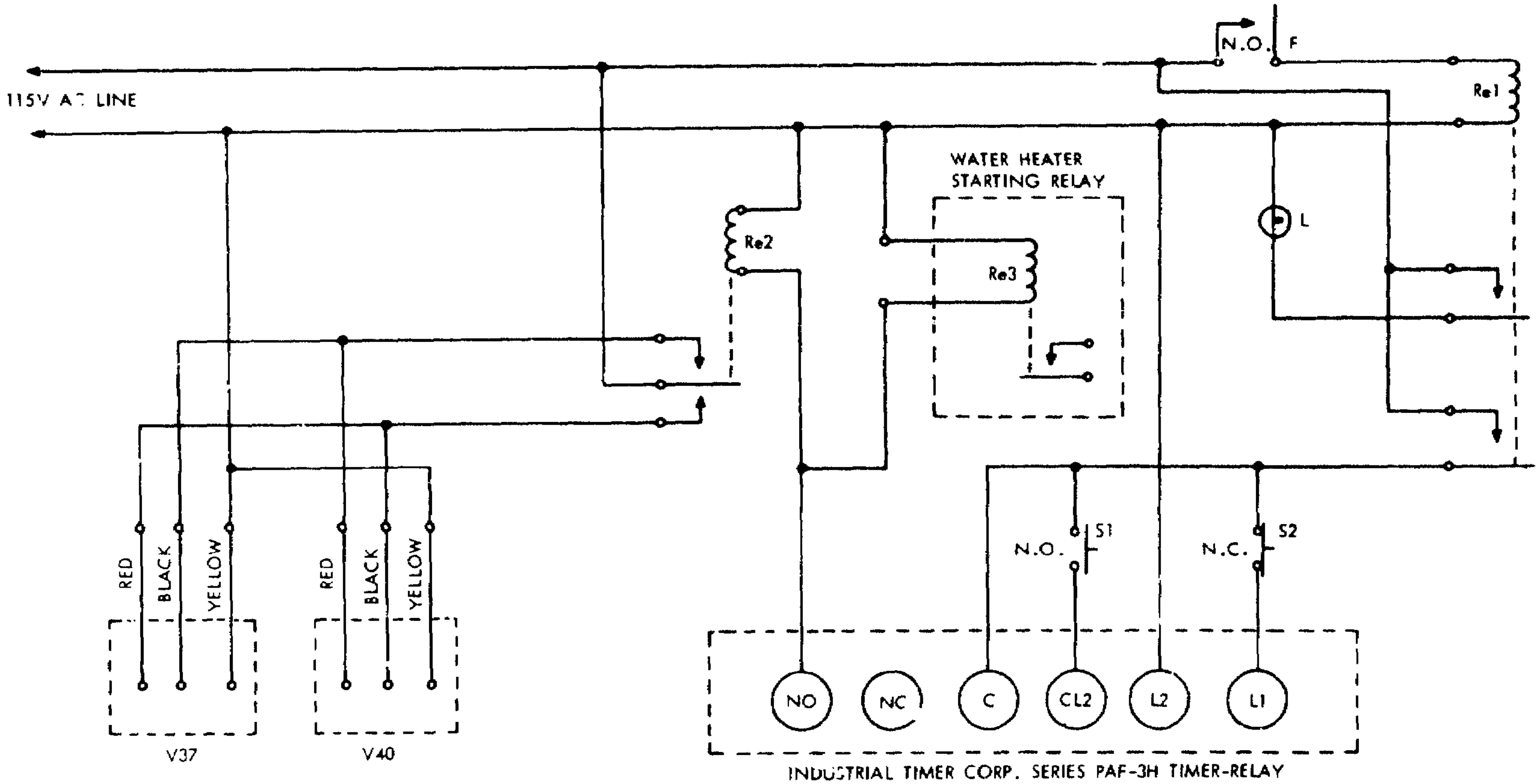
THE CONTROL SUBSYSTEM

2-39 The purpose of the control subsystem is to furnish automatic and remote control capabilities for safety and convenience in operating the filtration system. Figure 2-6 is a schematic diagram of the control subsystem.

2-40 When the water level in the testing tank falls one-half inch below its normal level, float switch S-1 will cause a placard labelled REFILL to light in the control room on the main floor of the test facility. At some convenient time, the operator will start the timer to begin the replenish operation. By starting the timer, the operator will be causing V-37 in the Replenish Subsystem to open and V-40 in the Skimmer Subsystem to close. This will also cause a third relay to actuate the Heater in the Replenish Subsystem if heating is required and if V-38 and V-65 in the Replenish Subsystem have been previously set for this heating option.

2-41 When the water in the testing tank again reaches the normal level, float switch S-2 will cause V-40 and V-37 to return to their normal operating conditions. If the water level has not reached the normal level before the timer completes its timing cycle, the timer will cause V-40 and V-37 to return to their normal operating conditions.

2-42 This completes the description of the filtration system. The appendicies that follow supplement the discussions of this report. The list of equipment given in Appendix C was developed from an attempt to juxtapose the general system requirements given in Chapter 1 upon the more specific component requirements given in Chapter 2. The absence of a recommended manufacturer for a component implies that almost any manufacturer's item would be acceptable.




F---FLOAT SWITCH (CONTACT POINTS ARE OPEN WHEN TANK IS AT PROPER LEVEL).
L---WARNING LAMP (INDICATING LOW WATER LEVEL).
S1---N. O. SPRING-RETURN SWITCH; PUSH TO START REFILLING OPERATION.
S2---N. C. SPRING-RETURN SWITCH; PUSH FOR MANUAL STOP REFILLING OPERATION.
Re1---115V AC RELAY, DPST.
Re2---115V AC RELAY, SPDT.
Re3---115V AC RELAY, SPST.
V37, V40---ELECTRICALLY-OPERATED (115V AC) VALVES. DURING REFILLING OPERATION, V37 IS OPEN AND V40 IS CLOSED. RAMCON CORP. MODEL 258-WP.

FIG. 2-6 SCHEMATIC DIAGRAM OF CONTROL SUBSYSTEM.

## APPENDIX A

### Calculations of Power Requirements for Main Pump Motor and Skimmer Pump Motor

I. Main Pump Motor Requirements

| Suction Side | *Equiv. Length Sch. 40 pipe (feet) | Uncorrected Loss (feet) | HEAD LOSS (feet) |
|---|---|---|---|
| Suction Lift | | | 2.00 |
| 4" gate valve (open) | 2.64 | | |
| | x 0.1'loss/10' | .02 | |
| 2" swing check valve | | 1.00 | |
| hair lint trap | 61.5 | | |
| (5) 90° long radius elbows @ 3.70 | 18.5 | | |
| | 80.0 | | |
| | x 2.7'loss/10' | 21.6 | |
| | | 22.8 | |
| | correction for smooth interior | x.54 | |
| | | | 12.3 |
| 4" PVC line (15') x1'loss/100' | | | .15 |
| | Suction HEAD LOSS | | 14.45 |
| 20' static head aids suction | | | -20.00 |
| | No NET Suction HEAD LOSS | | - |

*Assume 85 gpm

| Discharge Side | Equiv. Length Sch. 40 pipe (feet) | Uncorrected Loss (feet) | HEAD LOSS (feet) |
|---|---|---|---|
| Maximum filter loss = 20 psi | | | 46.2 |
| 4" PVC (70') x 1'loss/100' | | | 0.7 |
| 2" butterfly valve (VA) | 7.0 | | |
| (2) 2" ball valves (VD, V-6) @ 1.5 | 3.0 | | |
| | 10.0 | | |
| | x 2.7'loss/10' | 2.7 | |
| | correction for smooth interior | x.54 | |
| | | | 1.5 |
| 20' static head | | | 20.0 |
| | | | 68.4 |
| | | | (≐ 30 psi) |

Horsepower required to pump water

$$H = \frac{\text{GPM x Head}}{\text{3960 x Efficiency}}$$

GPM = 85 (by choice of filter)

Head = 68.4' (calculated above)

Efficiency = 50% (8" impeller on Armstrong 4020 1½E pump)

$$H = \frac{85 \times 68}{3960 \times .5} = 2.92 \text{ horsepower}$$

$\therefore$ Use 3 HP motor for main pump

II. Skimmer Pump Motor Requirements

Suction Side

A 20 foot static head aids suction in both skimming and replenishing operations. This will be sufficient to overcome all losses in both subsystems even at maximum filter loss in the replenish subsystem.

| Discharge Side | *Equiv. Length Sch. 40 pipe (feet) | Uncorrected Loss (feet) | HEAD LOSS (feet) |
| --- | --- | --- | --- |
| Maximum filter loss = 20 psi | | | 46.2 |
| 1½" diaphragm valve (V-48) | 1 | | |
| 1½" Swing check valve (V-50) | 12 | | |
| | 13 | | |
| x 1'loss/10' | | | 1.3 |
| 1½" PVC (50') x 1'loss/100' | | | .5 |
| static head | | | 20 |
| Max. Discharge Head | | | 68.0 (± 30 psi) |

*Assume 28 gpm

Horsepower required to pump water

$$H = \frac{GPM \times Head}{3960 \times Efficiency}$$

GPM = 28 (desired)

Head = 68.0' (calculated above)

Efficiency = 40% (assumed)

$$H = \frac{28 \times 68}{3960 \times .4} = 1.2$$

$\therefore$ Use 1.5 HP motor for skimmer pump

(Megator #L150 at 1100 rpm - see Appendix C)

LIST OF OPERATIONS

1. NORMAL OPERATION
2. MAIN CIRCULATION LOOP BACKWASH
3. MAIN CIRCULATION LOOP PRECOAT
4. MAIN CIRCULATION LOOP BY-PASS
5. SKIMMER SUB-SYSTEM BACKWASH
6. SKIMMER SUB-SYSTEM PRECOAT
7. REPLENISH SUB-SYSTEM BACKWASH
8. REPLENISH SUB-SYSTEM PRECOAT
9. SKIMMER FILTER CARTRIDGE CHANGE
   REPLENISH FILTER CARTRIDGE CHANGE
10. REPLENISH OPERATION
11. INITIAL FILLING OPERATION
12. EMPTYING TANK

Operation: NORMAL OPERATION

Purpose: The purpose of normal operation is to filter the main body of water in the testing tank and to skim debris off the surface using the skimmer subsystem.

Description: Water flows out the bottom of the testing tank through V-8 and into the trench through the 4" PVC line. The main pump discharge water through VA and into the main filter. The filtered water travels through VD and V-6 back to the top of the tank through the vertical 4" PVC pipe.

Water from the surface flows into the skimmer head and through V-40 and V-41 into the skimmer pump. From the discharge side, the water goes through the 3-way valve V-43 to the bottom of the cartridge filters. The discharge from these filters feeds through V-48, M-49, and V-50 on its way back to the top of the testing tank.

| Valve: | V8 | V10 | VA | VB | VC | VE | V1 | VD | V5 | V6 | V40 | V41 | V43 | V45 | V47 | V48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | C | O | C | C | C | C | O | C | O | O | O | * | C | C | O |

| | V20 | V27 | V28 | V29 | V30 | V32 | V34 | V36 | V37 | V38 | V65 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | C | C | C | C | * | C | C | C | ** | O |

* 3-way valve (Filter Position)
** 3-way valve (Pump Position)
Both the main pump and the skimmer pump are on in normal operation.

NOTES: Periodically check the pressure differential between inlet/outlet pressure gauges on both the main filter and on the skimmer filter. Backwash and precoat before this differential reaches 20 psi.

Operation: MAIN CIRCULATION LOOP BACKWASH

Purpose: The purpose of this operation is to clean the main filter by removing dirty diatomaceous earth from the elements of the filter.

Description: When ready to backwash, the operator must stop the main pump, close VD and VA, open VB and VC, then start the pump again. Water from the main tank is pumped into the main filter in a reverse direction to flush the diatomaceous cake off of the elements. The flushing water is directed to the drain via VB; the operator must watch G-14 and stop the main pump as soon as the flushing water looks clean. He must then immediately close VC to prevent more water draining from the main tank. Opening V1 will then let any water remaining in the filter drain out through VB. When the water has stopped flowing through G-14, close VB and the clean filter is ready for precoating.

| Valve: | VA | VB | VC | VD | V1 | Main Pump |
|---|---|---|---|---|---|---|
| Before | O | C | C | O | C | Off |
| During | C | O/C | O/C | C | C/O | On |
| After | C | C | C | C | O | Off |

Next Operation: MAIN CIRCULATION LOOP PRECOAT

NOTES: Strict attention must be paid to the sequence of valve and pump operations described above. A completely closed head on the discharge side of the pump will cause it to shut down automatically. Inadvertently leaving VB open can eventually lead to dumping all the water in the main tank to the drain.

Operation: MAIN CIRCULATION LOOP PRECOAT

Purpose: The purpose of the precoat operation is to re-establish the diatomaceous earth coating on the elements of the filter. It will always follow the backwash operation on the main filter.

Description: A diatomaceous earth slurry is prepared in the precoat-pot on the main filter body. Open the cock of this pot to allow the slurry to enter the filter tank, wash out the pot with water from the hose in the filtration room, then close the cock. Make sure V1 is open then open VA and start the main pump. This causes water to enter the filter tank and deposit the diatomaceous earth on the filter elements. When flow first begins to be seen in G-13, open VE and close V1, in that order. Watch G-13 until the water is absolutely clear; wasting a little water at this stage is preferable to introducing any "bleed through" diatomaceous earth into the main testing tank. Make sure that V-6 is open than open VD and close VE, in that order. Normal filtration is now resumed.

| Valve: | VA | V1 | VE | V6 | VD | Main Pump |
|---|---|---|---|---|---|---|
| Before | C | O | C | O | C | Off |
| During | O | O/C | C/O/C | O | C/O | On |
| After | O | C | C | O | O | On |

Next Operation: NORMAL OPERATION

NOTES: Valve sequences are important; observe them as described above. If they are not observed, the main pump might get automatically shut off because of a closed head, or some of the diatomaceous earth may be introduced into the main testing tank. Inadvertently leaving VE or V1 open can eventually lead to dumping all the water in the main tank to the drain.

Operation: MAIN CIRCULATION LOOP BY-PASS

Purpose: The purpose of the by-pass operation is to provide a method by which the pressure can be maintained on the main filter elements while stopping the return flow to the main testing tank. This will keep the diatomaceous earth cake on the filter elements and allow acoustic testing in the main tank to proceed at a reduced flow noise level.

Description: The discharge from the main filter is diverted from its return path to the testing tank and directed back to the suction side of the main pump simply by opening V-5 and closing V-6. Normal operation will be restored by opening V-6 and then closing V-5. The order of valve operation is important.

| Valve: | V5 | V6 |
|---|---|---|
| Before | C | 0 |
| During | 0/C | C/0 |
| After | C | 0 |

Next Operation: NORMAL OPERATION

NOTES: The order of operating V-5 and V-6 during the by-pass operation is important. If they are ever both closed, the main pump will see a closed head and will automatically stop. If they are both open, the flow back to the main tank will be reduced, but the water in the tank will only be filtered at a fraction of the intended rate.

Operation: SKIMMER SUBSYSTEM BACKWASH

<u>Purpose</u>: The purpose of this operation is to clean the skimmer filter by removing dirty diatomaceous earth from the elements of the filter.

<u>Description</u>: When the pressure differential between M-42 and M-44 nears 20 psi, stop the skimmer pump, open V-45 and switch V-43 to its backwash position; now restart the skimmer pump. Water from the main testing tank will be pumped into the filter cartridges in a reversed direction to flush the diatomaceous earth off. The flushing water is directed to the drain via V-45. Watch G-46 and <u>stop</u> the skimmer pump as soon as the flushing water looks clean. If the next operation will be to operate these cartridges without a diatomaceous earth coating, the operator <u>may</u> return V-44 to its filter position and then close V-45; the filtration cycle will then be restored when the pump is started. If the next operation will be to precoat the cartridges, the operator should drain as much water as possible out of the filter by leaving V-45 open about 2 minutes after he shuts off the skimmer pump. If water continues to flow after this time, the skimmer is siphoning water from the top of the main testing tank; the operator should stop this siphoning by closing V-41. When this last amount of water has drained from the filter, as determined by watching G-46, close V-45 to stop the flow of water to the drain and return V-43 to its filter position.

| Valve: | V45 | V43 | Skimmer Pump | (V41) |
|---|---|---|---|---|
| Before | C | F | On | 0 |
| During | 0/C | B | Off/On/Off | 0/C |
| After | C | F | * | 0 |

*On for no diatomaceous earth
Off for precoat or cart. change

Next Operation: SKIMMER SUBSYSTEM PRECOAT OR NORMAL OPERATION OR SKIMMER FILTER CARTRIDGE CHANGE

<u>NOTES</u>: Inadvertently leaving V-45 open can eventually cause a large loss of water from the main testing tank because all the water taken in by the skimmer would go to the drain via V-45.

If the operator chooses to operate the skimmer filter without a diatomaceous coating on the filter elements, he may proceed directly to NORMAL OPERATION. If this option is chosen, the cartridges will have to be replaced the next time the pressure differential between M-42 and M-44 nears 20 psi.

Operation: SKIMMER SUBSYSTEM PRECOAT

<u>Purpose</u>: The purpose of this operation is to re-establish the diatomaceous earth coating of the elements of the skimmer filter. This is not a <u>necessary</u> operation because these elements are disposable cartridges. Finer filtration may result by using diatomaceous earth, but experience may indicate that it offers no real advantage in the skimmer subsystem.

<u>Description</u>: A diatomaceous earth slurry is prepared and poured into the filter through the cap in the top and the cap is securely replaced. Open V-47, make sure V-43 is in its filter position, then start the skimmer pump. Water will enter the filter and deposit the diatomaceous earth on the filter elements. When the water flowing through G-46 becomes absolutely clear, make sure V-48 is open then close V-47. Adjust V-48 to make M-49 show a flow rate of about 28 gpm. Normal skimmer filtering is now resumed.

| Valve: | V47 | V43 | V48 | Skimmer Pump |
|---|---|---|---|---|
| Before | C | F | 0 | Off |
| During | 0/C | F | 0 | Off/On |
| After | C | F | 0 | On |

Next Operation: NORMAL OPERATION

<u>NOTES</u>: Inadvertently leaving V-47 open can cause a large loss of water from the main testing tank because all the water taken in by the skimmer would go to the drain via V-45.

If the operator notices any flow in M-49 before V-47 is finally closed, it may be necessary to close V-48 until all the "bleed through" diatomaceous earth has gone to the drain, as can be determined by watching G-46 after the pump starts in the above sequence.

Operation: REPLENISH SUBSYSTEM BACKWASH

Purpose: The purpose of this operation is to clean the replenish filter by removing dirty diatomaceous earth from the elements of the filter.

Description: Purge the municipal main by opening V-28; let the water run until the clarity is acceptable. Open V-20 on the main floor and then go to the filtration room. Open V-34 and switch V-32 to its backwash position. Fresh water from the municipal main will enter the filter cartridges in a reversed direction to flush the diatomaceous earth down the drain via V-34. Watch G-35 and close V-34 when the flushing water looks clean. If the next operation will be to operate these cartridges without a diatomaceous earth coating, return V-32 to its filter position; filtration will be restored when V-37 is opened and V-40 is closed by using the electrical actuation switch for these valves.

If the next operation will be to precoat the cartridges or to change them, drain as much water as possible out of the filter by closing V-30 (instead of V-34) when the flushing water looks clean; after about 2 minutes, close V-34. Return V-32 to its filter position.

| Valve: | V28 | V20 | V30 | V34 | V32 | V37 | V40 |
|---|---|---|---|---|---|---|---|
| Before | C | C | 0 | C | F | C | 0 |
| During | 0/C | 0 | 0 | 0/C | B | C | 0 |
| After | C | 0 | * | C | F | C | 0 |

*0 if not using diatomaceous earth
C if next step is precoat or cartridge change

Next operation: REPLENISH SUBSYSTEM PRECOAT OR NORMAL OPERATION OR REPLENISH FILTER CARTRIDGE CHANGE

NOTES: Because there will normally be no water flowing in the replenish subsystem, operation will probably be without the diatomaceous earth. During the initial filling operation, however, diatomaceous earth should be used. This will slow down the filling process because of the necessity of backwashing and precoating the replenish filter many times, but the resulting cleaner water should warrant this extra complication.

Operation: REPLENISH SUBSYSTEM PRECOAT

Purpose: The purpose of this operation is to re-establish the diatomaceous earth coating of the elements of the replenish filter. This is not a necessary operation because these elements are disposable cartridges. Finer filtration may result with diatomaceous earth, but experience may indicate that its use during normal operation of the filtration system is a disadvantage because of the necessity of going through the backwash-precoat sequence each time new water is to be added to the system from the municipal main.

Description: A diatomaceous earth slurry is prepared and poured into the filter through a cap in the top and the cap is securely replaced. Open V-36, make sure V-32 is in its filter position, then open V-30. (V-20 on the main floor of the facility should already be open.) Water from the municipal main will enter the filter and deposit the diatomaceous earth on the filter elements. When the water flowing through G-35 becomes absolutely clear, make sure the skimmer pump is running then close V-36. Hurry back to the electrical actuation switch that opens V-37 and closes V-40 and start the replenish cycle. The point of hurrying to start the replenish cycle is to minimize the time the diatomaceous earth has to slip off the cartridge elements while there is no water flowing through the filter. The "bleed through" from this filter will not be a real concern because the output of the replenish filter will pass through the skimmer filter before entering the main testing tank.

| Valve: | V36 | V32 | V30 | V20 | V37 | V40 |
|---|---|---|---|---|---|---|
| Before | C | F | O | O | C | O |
| During | O/C | F | O | O | C/O | O/C |
| After | C | F | O | O | O | C |

Next Operation: REPLENISH OPERATION

NOTES: Inadvertently leaving V-36 open can wastefully direct water from the municipal main to the drain.

The replenish operation must follow this precoating operation in order to keep the diatomaceous earth on the cartridge elements. Experience with the system will indicate whether or not the replenish subsystem should be operated with diatomaceous earth as a routing practice. This experience may show that a forming-slip off-forming sequence using the same diatomaceous earth is acceptable because the skimmer filter backs up the replenish filter and filters its output.

Operation: SKIMMER FILTER CARTRIDGE CHANGE
REPLENISH FILTER CARTRIDGE CHANGE

Purpose: The purpose of this operation is to replace the disposable cartridge filters in the named subsystem.

Description: Follow the BACKWASH operation for the subsystem. selecting the options indicated for cartridge changes. When the water is out of the filters, follow the filter manufacturer's directions for removing the cartridges from the filters. This will simply consist of releasing a "T" handle catch on the top of the filters, tilting the top back, pulling the cartridges out, putting new cartridges in and closing the top. The next operation following in this replacement may be normal operation without a diatomaceous coating on the filter cartridges or it may be the precoating operation for that filter for which the operator would follow the PRECOAT operation.

Operation: REPLENISH OPERATION

Purpose: The purpose of this operation is to restore the level of the water in the main testing tank to its required height. A "REPLENISH TANK" sign will light in the main control room when the water is approximately ½ inch below its required level. This lowered level may have been caused by a combination of evaporation, leakage and losses during backwashing and precoating operations.

Description: If the replenish subsystem is operating without a diatomaceous earth coating on the filter, open V-28 on the main floor to purge the municipal main. When the water is clear, make sure V-20 on the main floor is open and then activate the replenish cycle timer in the main control room. This will cause V-37 to open and V-40 to close and to remain in these conditions until the timer completes it preset timing cycle or until the water in the testing tank causes the "full" float switch to stop the cycle by opening V-40 and closing V-37.

If the replenish subsystem is operating with a diatcmaceous earth coating on the filter, begin the replenish operation by starting with the REPLENISH SUBSYSTEM BACKWASH operation and follow by the REPLENISH SUBSYSTEM PRECOAT operation. The end of this last operation automatically begins the replenish cycle.

Sometime after the replenish operation is begun, using either of the conditions described above, the operator should check the pressure differential between M-31 and M-33. If it is nearing 20 psi, he should backwash and precoat or change cartridges as required and as described in the REPLENISH SUBSYSTEM BACKWASH and REPLENISH SUBSYSTEM PRECOAT, or REPLENISH CARTRIDGE CHANGE operational instructions.

Operation: INITIAL FILLING OPERATION

<u>Purpose</u>: The purpose of this operation is to fill the main testing tank with clean, filtered water for the first time.

<u>Description</u>: At the beginning of this initial filling operation, the operator should complete the check-out procedure described in paragraph A.

A. Flush the municipal main by opening V-28 and letting the water run until it is clean; close V-28. (Opening faucets in the building will help this flushing operation.) Introduce water into the replenish subsystem by opening V-20 on the main floor, V-30 in the replenish subsystem, and V-34 going to the drain; this will flush out the replenish filter. (V-32 may be in either its filter or its backwash position.) Next, shift V-32 between its two positions several times to determine if it's working properly and smoothly; end with it in its filter position. Open V-36 and close V-34 so that the replenish filter fills but sends its output to the drain. Set V-38 at its pump position. Open V-37 and close V-40 by using the electrical actuation switch for the replenish cycle. Make sure V-41 is open, open V-45, and fully open V-48; V-43 may be in either of its two positions for this. Now close V-36 in the replenish subsystem so that water flows through the replenish filter and to the pump in the skimmer subsystem. Start this pump. Move V-43 between its two positions several times to check its operation. Open V-47 and close V-45 to fill the skimmer filter but send its output to the drain. Close V-47 and adjust V-48 to a flow rate of 28 gpm determined by reading M-49. When the first water enters the main testing tank, this check-out procedure is completed; the filters must next be coated with diatomaceous earth.

<u>NOTE:</u> The diatomaceous earth coating should be applied to <u>both</u> the replenish and the skimmer filters. The following process for precoating will apply during the initial filling operation until the skimmer suction line is placed in contact with the water in the testing tank. To prevent the filling procedure from being automatically terminated, THE TIMING SWITCH FOR THE REPLENISH CYCLE MUST BE BY-PASSED UNTIL THE SKIMMER SUCTION LINE IS IN CONTACT WITH THE WATER IN THE TESTING TANK.

B. To precoat the skimmer and the replenish filters, stop the skimmer pump and close V-30. Open V-34 and V-45 to drain both the replenish and the skimmer filters. When the water has stopped flowing through G-35 and G-46, close V-34 and V-45. Make sure V-32 and V-43 are in their filter positions. Prepare a diatomaceous earth slurry according to the filter manufacturer's instructions, pour it into the filters through caps in their tops, replace the caps and secure them tightly. Open V-36 and V-47, make sure V-38 is in its pump position, MAKE SURE V-37 IS OPEN, open V-30. When the water flowing through G-35 becomes absolutely clear, start the skimmer pump and close V-36. When the water flowing through G-46 becomes absolutely clear, make sure V-48 is open enough to adjust the flow rate then close V-47. Clean water should start entering the main testing tank from the skimmer return line at a flow rate of 28 gpm. This filling should continue until the filters need backwashing as explained in paragraph C.

C. When the pressure differential between M-31 and M-33 or between M-42 and M-44 nears 20 psi, both filters should be backwashed and precoated. Open V-45 and change V-43 to its backwash position. When the water flowing through G-46 becomes clear, open V-34 and change V-32 to its backwash position. When the water flow through both G-35 and G-46 becomes clear, stop the skimmer pump and close V-30.

Go back to step B above. Keep repeating this filling-backwashing-precoating cycle until the main testing tank is about half full of water or until the skimmer suction line has been placed so that the skimmer pump can see a flooded suction when V-40 is open and V-37 closed. At such a time, the operator has the option of repeating the cycle of paragraphs B and C above or of proceeding to the SKIMMER and REPLENISH SUBSYSTEM BACKWASH and PRECOAT operations when these filters require backwashing separately (as opposed to backwashing them jointly in the cycle of paragraph B and C above.)

D. When the main testing tank is about half full of water, the operator may activate the main circulation loop as here described. The decision should be based on how far down into the tank the outlet from the main circulation loop has been placed. If the exit nozzle is above the surface of the water in the tank, turbulence will introduce large amounts of air into the water as it falls from the nozzle to the surface.

First, open the following valves: V-8, VA, VE and V-6. Close V-10, VB, VC, VD, V1 and V-5. Start the main pump and watch G-13. When the water flowing through G-13 is clear, open VD and close VE. Water should now start entering the main testing tank through the return from the main circulation loop. Now proceed to the MAIN CIRCULATION LOOP BACKWASH operation to put this system into normal operation. Backwashing and precoating will be required in this subsystem whenever the pressure differential between the inlet and outlet pressures, as indicated on the pressure gauges mounted on the main filter, nears 20 psi. When the main testing tank is full to the required height, the total system should be in its NORMAL OPERATION condition if all the preceeding instructions have been followed.

Operation: EMPTYING OF MAIN TESTING TANK

<u>Purpose</u>: The purpose of this operation is remove some or all of the water in the main testing tank as rapidly as possible. This is a drastic step and should be carried out only for emergencies or for repair operations on the tank. There is a danger of damaging the wooden tank staves if the previously soaked interior is allowed to dry and shrink.

Description: With V-8 open, open V-10. An alternate path is by opening both VA and VB.

# APPENDIX C

## LIST OF RECOMMENDED EQUIPMENT

C-1 This Appendix lists the components recommended for use in the filtration system. These components have been selected on the basis of their apparent reliability, maintainability, replacement part availability, corrosive resistance when used in combination with other materials in the system, and capability for minimizing flow and noise associated with operation of the filtration system either through design or through mounting technique or both. Measures of some of these considerations are the component size, its configuration and its material of manufacture. A list of the names and addresses of the manufacturers of these recommended components follows the list of equipment.

NOTE: All valves and fittings must be rated at 100 psig steam or 175 psig non-shock cold water or better.

## MAIN CIRCULATION LOOP

V8 Gate Valve - 4", screwed, bronze - Jenkins Bros. Fig. 676A
Acoustic Decoupler - 4", flanged, 24" long - Korfund Dynamics Corp., Type RHF

V9 Swing Check Valve - 2", screwed, bronze, soft resilient disc No. 125 Jenkins Bros. Fig. 352
Hair-lint Trap - 2", flanged, bronze - Hayward Mfg. Co. Model 72
(Suction) Acoustic Decoupler - 2", screwed, 24" long - Korfund Dynamics Corp. Type RHM
Main Pump - 8" impeller, open drip-proof 3HP motor, 208V, 3 phase Armstrong Pumps, Inc. Series 4020, Pump Size 1½E
Magnetic Contactor - NEMA Type I
(Discharge) Acoustic Decoupler - 1½", screwed, 18" long-Korfund Type RHM
Pressure Limit Switch - The Mercoid Corp. Type DA-21-2L, range 5S

| | | |
|---|---|---|
| VA | Butterfly Valve - 2" | Furnished with main filter as components in header |
| VB | Butterfly Valve - 2" | |
| VC | Butterfly Valve - 2" | |

VD Ball Valve - 2", flanged bronze, reinforced TFE, Hills-McCanna 2" - S151-Br-R-Br

V1 Vent Valve- Furnished with main filter
Main Filter - Diatomaceous earth filter, 20 hr. turnover of 102,000 gal. Bowser Inc., Model 610-E-42 with header, pressure gauges, precoat-pot

V10 Globe Valve - 2", flanged, bronze - Jenkins Bros. Fig. 107A disc 294-S

G13 Sight Glass - 1½", bronze, screwed - Schutte and Koerting Type 1882

G14 Sight Glass - 2", bronze, flanged - Schutte and Koerting Type 1804

V5 Butterfly Valve - 2", flanged, Dover Corp. Norriseal Model P2030-431-1B

V6 Ball Valve - 2", flanged, bronze, reinforced TFE, Hills-McCanna 2"-S151-Br-R-Br

Acoustic Decoupler - 2", screwed, 24" long - Korfund Dynamics Corp. Type RHM

Vibration isolating pipe hanger - Korfund Dynamics Corp.

Other Materials:

Misc. Fittings: Bronze

Pipe: 4" PVC Type 1 1120 Schedule 80

Pipe: 2", 1½" Bronze

NOTE: All valves and fittings must be rated at 100 psig steam or 175 psig non-shock cold water or better.

## SKIMMER SUBSYSTEM

Skimmer - Swimquip, Inc. Model U-3 #8655
Pump - Megator Corp. - Snore Pump #L150 bronze V-belt, 1.5 HP, rpm Motor (SS port plate, nitralloy steel rotor, nitrile shoes)
Flexible Hose - 1½" wire reinforced PVC

V40 Ball Valve - Hills-McCanna 1½"-S151-Br-R-Br, Bronze, flanged, reinforced TFE
Valve Actuator - Ramgon Corp. Model 25B

V41 Ball Valve - Hills-McCanna 1½"-S152-Br-R-Br, bronze, screwed, reinforced TFE
Pressure Limit Switch - The Mercoid Corp. Type DA-21-2L Range 5S
Magnetic Starter - NEMA Type 1

M42 Pressure Gauge - Marsh Instrument Co. 3½" diam., 0-60 psig, ¼" N.P.T. male bottom connection, bronze, bellows

V43 Three-way, 2 position Valve - Quality Controls, Inc., Screwed 1¼" 3119L (seq. 1212)
(2) Cartridge Filters - Bowser Inc. Model 611-7 (88862 Cartridges)

M44 Pressure Gauge - Marsh Instrument Co. 3½" diam, 0-60 psig, ¼" N.P.T. male bottom connection, bronze, bellows

V45 Globe Valve - 1¼" bronze, screwed, - Jenkins Bros., Corp. Fig. 106A, medium soft disc No. 294S

G46 Sight Glass - 1¼", bronze, screwed - Schutte & Koerting Type 1882

V47 Globe Valve - 1¼" bronze, screwed - Jenkins Bros., Corp. Fig. 106A medium soft disc No. 294S

V48 Diaphragm Valve - 1½", bronze, screwed TFE solid diaphragm - Hills-McCanna 1½"-J611-2J1

M49 Flow Rate Meter - Fischer & Porter 1½" Model 10F1025B service clamp for series 10F1020 Flow indicator

M50 Swing Check Valve - 1½" bronze, flanged, soft resilent disc No. 125 Jenkins Bros. Fig. 353
Other Materials:
Misc. Fittings: Bronze
Pipe: 1½" PVC Type I 1120 Schedule 80
Pipe: 1½" and 1¼" bronze

NOTE: All valves and fittings must be rated at 100 psig steam or 175 psig non-shock cold water or better.

REPLENISH SUB-SYSTEM

V20 Globe Valve - 1½", screwed, bronze - Jenkins Bros., Corp. Fig. 106A medium soft disc No. 294-S

V27 Globe Valve - 1½" "

V28 Globe Valve - 1½" "
In-line Thermometer - Weston Model 2281; 4"; 25 to 125°F in 1°

V29 Hose Bibb - 3/4"

V30 Globe Valve - 1¼", screwed, bronze, Jenkins Bros., Corp. Fig. 106A medium soft disc No. 294-S

M31 Pressure Gauge - Marsh Instrument Co., 3½" diam., 0-60 psig, ¼" N.P.T. male bottom connection, bronze bellows

V32 Three-way Valve - 1¼", screwed, bronze, Quality Controls, Inc. 3119L (seq. 1212)
(2) Cartridge Fitters - Bowser Inc. Model 611-7 (88862 Cartridges)

M33 Pressure Gauge - Marsh Instrument Co., 3½" diam., 0-60 psig, ¼" N.P.T. male bottom connection, bronze bellows

V34 Globe Valve - 1¼" bronze, screwed - Jenkins Bros., Corp. Fig. 106A medium soft disc No. 294-S

G35 Sight Glass - 1¼" bronze, screwed - Schutte & Koerting Type 1882

V36 Globe Valve - 1¼" bronze, screwed - Jenkins Bros., Corp. Fig. 106A medium soft disc No. 294-S

V37 Ball Valve - 1½" bronze, flanged, reinforced TFE seat, Hills-McCanna 1½"-S151-Br-R-Br
Actuator - Ramcon Corp. Model 25B

V38 Three-way Valve - 1½" screwed, bronze, Quality Controls 3119L (seq. 1212)

V65 Diaphragm Valve - 1½" screwed, bronze, TFE solid diaphragm Hills-McCanna 1½"-J611-2-J1

M66 Flow rate meter - Fischer & Porter 1½" Model 10F1025B service clamp for Series 10F1020 Flow rate indicator

H68 Heater - INDEECO Model 56W-20KW (with thermostat and other accessories)
Misc. Fittings: Bronze
Pipe: 1½" PVC Type I 1120 Sch. 80
Pipe: 1½" and 1¼" bronze

## NAMES AND ADDRESSES OF MANUFACTURERS FOR RECOMMENDED COMPONENTS OF FILTRATION SYSTEM

1. Armstrong Pumps Incorporated
   Lockport, New York 14094

2. Bowser Incorporated
   Bowser - Briggs Filtration Division
   Cookeville, Tennessee

3. Dover Corporation/Norris Division
   P.O. Box 1739
   Tulsa, Oklahoma 74101

4. Fischer and Porter Company
   Warminster, Pennsylvania 18974

5. Hayward Manufacturing Company, Incorporated
   900 Fairmount Avenue
   Elizabeth, New Jersey 07207

6. Hills - McCanna Company
   400 Maple Avenue
   Carpentersville, Illinois 60110

7. Industrial Engineering and Equipment Company
   425 Hanley Industrial Court
   St. Louis, Montana 63144

8. Industrial Timer Corporation
   U. S. Highway 287
   Parsippany, New Jersey 07054

9. Jenkins Bros. Corporation
   Bridgeport, Connecticut 06609

# NAMES AND ADDRESSES OF MANUFACTURERS FOR RECOMMENDED COMPONENTS OF FILTRATION SYSTEM

10. Korfund Dynamics Corporation
    Cantiague Road
    Westbury, Long Island, New York 11590

11. Marsh Instrument Company
    Wilmette, Illinois 60091

12. Megator Corporation
    136 Gamma Drive
    Pittsburgh, Pennsylvania 15238

13. Mercoid Corporation
    4201 Belmont Avenue
    Chicago, Illinois 60641

14. Quality Controls Incorporated
    910 Eastern Avenue
    Malden, Massachusetts 02148

15. Ramcon Corporation
    1725 Fleetwood Drive
    Elgin, Illinois 60120

16. Robertshaw Controls Company
    Fulton Sylphon Division
    Knoxville, Tennessee 37901

17. Schutte and Koerting Company
    Cornwells Heights, Pennsylvania 19020

18. Swimquip Incorporated
    1121 Huff Road, N. W.
    Atlanta, Georgia 30324

19. Weston Instruments Incorporated
    614 Frelinghuysen Avenue
    Newark, New Jersey 07114

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13. ABSTRACT

This report presents a discussion of a filtration and water control system for a proposed underwater acoustic test facility. It specifies functional requirements for the components and subsystems of a filtration system and, based on these requirements, it presents a detailed design for such a system.

| 14 KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Filtration | | | | | | |
| Water Filtration | | | | | | |
| Diatomaceous Earth | | | | | | |
| Acoustic Test Facility | | | | | | |